JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CLII, No. 3. 76TH YEAR. SEPTEMBER, 1901

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THE FRANKLIN INSTITUTE.

Stated Meeting, held Wednesday, April 17, 1901.

THE TAYLOR-WHITE PROCESS OF TREATING TOOL STEEL,

AND

ITS INFLUENCE ON THE MECHANIC ARTS.

BY CHARLES DAY,
The Link-Belt Engineering Company,
Member of the Institute.

I have been asked to give you this evening, a brief description of the Taylor-White process of treating tool steel, with special reference to our work at the Link-Belt Engineering Company (Nicetown, Philadelphia).

I will first take up the process, which has been but recently patented here and abroad. The first experiments, which led to the very thorough investigation later, and finally to the Taylor-White process, were carried out between three and four years ago at the Bethlehem Steel

Works (South Bethlehem, Pa.) by Messrs. Taylor and White. At that time "Mushet" and "Jessop" tool steels were in general use throughout their shop, the former representing the best grade of air-hardening steel on the market. The usual method of hardening all air-hardening steel is well known, and the manufacturers in nearly every case place great stress on the fact that the tool must not be heated above a cherry red, otherwise it will be burnt, and so ruined. Not being satisfied with the limited information at hand on this matter, and having had some curious experiences with so-called burnt tools, Messrs. Taylor and White decided to make an investigation of the matter on a thoroughly scientific basis.

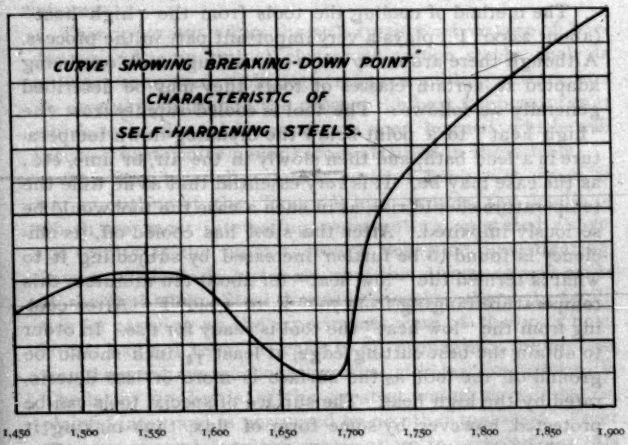
Many grades of air-hardening steel have been on the market for several years, and for roughing work have unquestionably replaced the carbon variety, the efficiency of the former ranging from one and a half to twice that of the latter. This gain is due to the fact that air-hardening steel holds its cutting edge at much higher temperatures than carbon steel, and consequently can be worked at proportionately greater cutting speed. The object in view in carrying out the experiments above referred to, was to obtain a tool steel which would give still better results than those already obtained, and how successfully this end has been attained is only too well known by those interested in machine-shop work.

The experiments consisted essentially in a long series of tests made upon tools of various chemical compositions, and heated to different temperatures. These tools, after being carefully ground to the desired angles, were tested in an experimental lathe, provided with a motor drive and an "Evans" friction cone, in order to obtain any desired cutting speed. Most careful records were made of all these tests, which extended over several years. The results which were finally arrived at, and recently patented, are truly astonishing, the treated tools showing an efficiency ranging from one and one-half to two and one-half times that of air-hardening steel treated by the old method.

The discovery of the new process depends largely on the

fact that, although both carbon and air-hardening steel deteriorate rapidly when the temperature rises above a cherry red, some chemical compositions of the latter class rapidly pass through this condition, the efficiency rising slowly at first, and very rapidly as the temperature rises, reaching a maximum at the point where the tool crumbles when tapped with a rod. This action can best be shown graphically, the abscissæ representing temperatures, and ordinates cutting values.

Link-Belt Engineering Company, Nicetown, Philadelphia.



This curve does not represent any particular piece of steel, but is intended to give a general idea only of the variations of the temperature to which the tool is heated, and the accompanying cutting values. The point to which air-hardening steel was formerly heated in the process of hardening is shown on the graphical sketch between 1,550° F. and 1,600° F., and has been called the "breaking down point," and varies, as do the other points, with different compositions of steel. The composition found to give the

best results consists of an air-hardening steel containing at least ½ of 1 per cent. chromium and 1 per cent. or more of another member of the same group, tungsten being found to give the best results. Much better results are obtained, however, by using about 1 per cent. of chromium and about 4 per cent. of tungsten; while for very hard metals, such as the chilled scale on cast iron, etc., 3 per cent. of chromium and 6 or more per cent. of tungsten are especially good. It may be interesting to note that the variation in carbon seems to matter but little, steel varying from 85 to 200 points giving equally good results.

The method of cooling the tools from the "high heat" (about 2,000° F.) plays a very important part in the process. Although there are many ways of cooling, each one being adapted to certain classes of tools, they may be described generally as follows: The tool is cooled rapidly from the "high heat" to a point below the breaking-down temperature in a lead bath, and then slowly in the air, or lime, etc., as the case may be. It is very essential that at no time the temperature should rise, as in such a case the tool would be seriously impaired. After the steel has cooled off, its efficiency is found to be further increased by subjecting it to what is termed the "low heat" for about ten minutes; this temperature ranging from 700° F. to 1,240° F. After cooling from the "low heat" the tool is ready for use. In order to obtain the best cutting edge, at least $\frac{1}{16}$ inch should be ground off the tool, as the surface is more or less deteriorated by the high heat. The surface of special tools can be protected, however, by some form of flux, thus making it possible to treat milling cutters, etc., by this process. The treatment in all cases extends well back from the point of the tool, and permits of its being ground until so weakened as to require reforging. It is not essential to anneal the steel when reforging, and it might be well to add that all these tools can be worked with comparative ease.

In the operation of the Taylor-White process apparatus is employed by means of which temperatures can be controlled within very narrow limits, which accounts for the uniformity of results obtained with the tools treated by this

process. It has been found necessary to modify the treatment of the special steel used in this process in order to obtain the best results under different conditions, such as varying kinds of metal cut on different types of machines, such as lathes, planers, slotters, drill presses, etc., so that no less than ten different modifications of the treatment are used in the preparation of tools for a large and fully equipped shop working on different kinds of metals and with various classes of tools. The variations required, however, in the treatment are of the most simple and easy application after once being understood, and can be handled with the full degree of success by an ordinary trained laborer.

This apparatus offers the still further advantage of hardening and tempering all classes of carbon steels, such as ordinary tempered tools, taps, reamers, milling cutters, etc. By careful operation of the process the best temperatures at which to harden and temper are soon learned, which will insure a uniformity never before attained in these tools.

The very brief description which I have just given, is but an outline of the Taylor-White process, the details of which are most interesting, representing, as stated above, the results of the most thorough scientific investigation. It was particularly fortunate that this discovery was made at the Bethlehem Steel Company's works, where the facilities for carrying on the experiments were of the very best. If this had not been the case, in all probability the process would never have reached its present standard or uniformity. The latter quality is of the greatest value, as will be explained later, and is possessed by no other tool steel. Over 200 tons of steel forgings were cut up in carrying out this work, and the total cost aggregated about $100,000.

A better example could not be found of the modern methods adopted in attacking problems of this nature. They bring rich results in nearly every case. Any number of examples could be cited, but probably one of the most interesting, and, at the same time, richest in results, was the work of Captain Jones on the ingot mold at the Edgar Thompson Works at Pittsburg. These molds, in nearly every

case, cracked after a few ingots were cast, the expense this involved being enormous. Realizing the necessity of more durable molds, and learning from experience that some ful. filled the requirements much better than others, Captain Jones undertook an investigation on the lines we have referred to above, the results paying a handsome dividend on the entire plant. And so it is in every line of manufacture, that the concern which has the facilities and is willing to spend the necessary money for work, which, at first sight, often seems entirely unnecessary, makes strides which not only cheapen its own product, but affect the entire business world.

The Taylor-White process of treating tool steel is particularly of this character, and has already wakened up machine shops all over the country to the fact that methods frequently known as "good shop practice" are anything but *good*, and if they expect to keep up with the times they must adopt different plans and more radical methods.

It will now possibly be well to consider some of the savings effected at the Link-Belt Engineering Company's works since this process was introduced. The class of work in this company's machine shop being radically different from any encountered by Messrs. Taylor and White up to the time we adopted the process, the first few months were devoted almost entirely to experimental work, the steel having been in general use throughout the shops for only a couple of months. For this reason it is impossible to give any data extending over considerable time, but a few examples taken at random will convey a fair idea of gains we have made.

About 97 per cent. of our material is cast iron, requiring much handling and relatively little machine work. In order to make a rough test on cast iron, one tool was obtained from Bethlehem and put to work on a 7-foot boring mill turning the inside of a cast-iron ring. The time required to do this work with our old tools had been determined many times in setting piece rates, and was about fourteen hours. With the Taylor-White tool this time was reduced to three and one-half hours, and a gain of 75 per cent. made. To be

sure, the steel used heretofore was not the best obtainable, and, besides, was probably not worked to its highest efficiency, but the saving, nevertheless, was due to the Taylor-White process, and so it is that many shops of the best standing could, after introducing this "process" and watching it with proper diligence in the shop, show savings considerably in advance of those claimed by the inventors. I do not wish to infer that there are not shops in existence who push every tool to its limit, but they are decidedly the exception.

Some interesting data was also obtained from an order of rope sheaves, the time required to do similar work having been tabulated for several years. The average time required to machine thirteen sheaves with our old tools was nine and one-half hours, the same for sixteen similar sheaves, the roughing being done by Taylor-White tools, was five hours and five minutes, or a saving of 46½ per cent. In order to obtain, however, a correct comparison of the relative merits of the tools used for roughing, it is necessary to analyze the various operations.

	Hours.
Setting up	·9
Forming groove with special tool	·5
Boring and polishing	·25
Roughing	3·43
	5·08

Assuming the time for setting up, forming, boring and polishing the same when sheaves were finished with old tools, the time for roughing would have been 7·85 hours. From these figures, we see that a saving of 56·3 per cent. was made in operations where it was possible to use treated tools.

The entire order of sheaves above referred to, many of which were small, the roughing cuts being but a small percentage of the machining, required 1,569 hours' work. This was a gain of 501¼ hours, or 31·95 per cent. over our *best* previous records, and gives a good idea of what may be expected on work of this class.

Tools treated by this process are not intended for finish-

ing, but rather for heavy cuts, where the tool is subjected to high heat. We have experimented quite a little with special tools, and have been very successful with boring cutters, the actual time for boring being reduced frequently 60 per cent. Here the tool saving is not as great as the figures would suggest, as the time to chuck a sprocket is at present often greater than to machine the same. The trouble lies in the design of the lathe that handles our sprockets, which we are at present remodelling in order to reduce the time of chucking, and similar operations to a minimum. A test made on boring cutters treated by the process shows conclusively their superiority for this work. It consisted in boring 1 $\frac{3}{16}$ inch standard solid collars in one cut, the core being one inch. The lathe was speeded up until the work at the point of the cutter was going 77 feet per minute. The regular cutter lasted but ten seconds, while the treated ones bored four (4) collars successfully.

In order to obtain some data with regard to pressure on the points of tools for given depths of cut, feed, etc., and at the same time to show the superiority of the treatment we are considering, a cast-iron ring 6 feet 6 inches in diameter was bolted to the table of a 7-foot boring mill and the results obtained tabulated below:

The first tool used was one treated for hard material. It cut 106 pounds of metal in 10 minutes, and when removed was in perfect condition. A "Mushet" tool under the same conditions lasted but one minute, and removed 5$\frac{1}{4}$ pounds of metal. The actual pressure against the tool in each case exceeded 3$\frac{1}{4}$ tons, while the pressure per square inch with the Me. S. H. tool was 143,000 pounds. Friction of the tool against the work was not considered in the above, and would vary the results somewhat.

We will now turn our attention to steel for a few moments, and although we have very little roughing work of this character I can recall several instances where good savings were effected, any one of which will serve as an example. One of our standard forms of internal screw conveyor is provided with steel tires about 40 inches in diameter and 40 points carbon. These are machined all over, the

Link-Belt Engineering Company, Nicetown, Philadelphia.

NO.	TOOL	MATERIAL	CIRC. SPEED		FEED		DEPTH CUT	LENGTH CUT		POUNDS METAL	AMMETER		VOLTMETER		HP		LBS. METAL PER HOUR	CONDITION TOOL	PRESSURE ON TOOL	
			IDLE	CUT.	CHECKING	ACTUAL		INCHES	MIN.		IDLE	CUT.	IDLE	CUT.	IDLE	CUT.			ACTUAL	PER SQ. INCH
1	H.S.H. TREATED 3/8 × 1 1/2"	C. I. SCALE	86	78	1/16	.056	.91	2 5/16	10	106	32	145	112	106	4.80	20.5	636	GOOD	6650	130,000
2	M.E.S.H. TREATED 1" × 2"	"	86	77	1/16	.053	.91	1 3/8	7 1/2	80	33	145	112	108	4.96	21.0	640	FAILED	6905	143,000
3	MUSHETT AIR-HARDENED 1" × 2"	"	86	—	1/16	—	.91	—	1	5 1/2	33	110	112	109	4.96	16.1	—	"	—	—
4	M.E.S.H. NOT TREATED	"	86	77	1/16	—	.91	—	1 3/8	7	32	110	116	110	4.98	16.2	—	"	—	—
5	H.S.H. NOT TREATED	"	86	—	1/16	—	.91	—	2 5/8	19	32	110	116	110	4.98	16.2	—	"	—	—

Tests made on cast-iron ring 6 feet 6 inches diameter. Boring mill, No. 191.

best time required for the entire operation of setting up, roughing, finishing, etc., etc., with our old tools being 14 hours; this was reduced to 9½ hours, or a saving of 32·1 per cent. on the first order received after treated tools were in use.

Our experience on steel has been so limited that we will take the liberty to quote some figures obtained at the Bethlehem Steel Works, who have very kindly sent us some samples, which are before you. The table given below shows the chips cut in pounds per hour per tool, the data

Table showing increase in cutting speed, etc., in the machine shop of the Bethlehem Steel Company, since the introduction of the Taylor-White process.

AVERAGE.	OCT. 25 1898	MAY 11 1899	JAN. 15 1900	GAIN IN % CUT OF 3RD OVER 2ND	GAIN IN % CUT OF 3RD OVER 1ST
CUTTING SPEED	8'-11"	21'-9"	25'-3"	16%	183%
DEPTH OF CUT	.23"	.278"	.30"	8%	30%
FEED	.07"	.0657"	.087"	32%	24%
LBS. METAL REMOVED PER HOUR	31.18	81.52	137.3	68%	340%
TENSILE STRENGTH	95,000	102,322	105,764*	3⅜%	11⅛%
% EXTENSION	.19%	.163%	.15%	8⅝%	
% CARBON	.44%	.42%	.42%		

* High tensile strength due to large amount of nickel steel being machined.

Average metal removed per hour, per tool (round nose) = 310 pounds.
April, 1901.

extending over the time the experiments were being developed, and are consequently, very interesting.

The steel chips which are before you show the characteristic colors which are the gauge for the speed foreman. A Taylor-White tool when working dry should cut blue chips continuously, so it is only necessary to turn off the water for a moment in order to see if the tool is working to its highest efficiency. The cutting speed may be increased about 30 per cent. if a good stream of water is kept on the point of the tool. It may be interesting to some to know

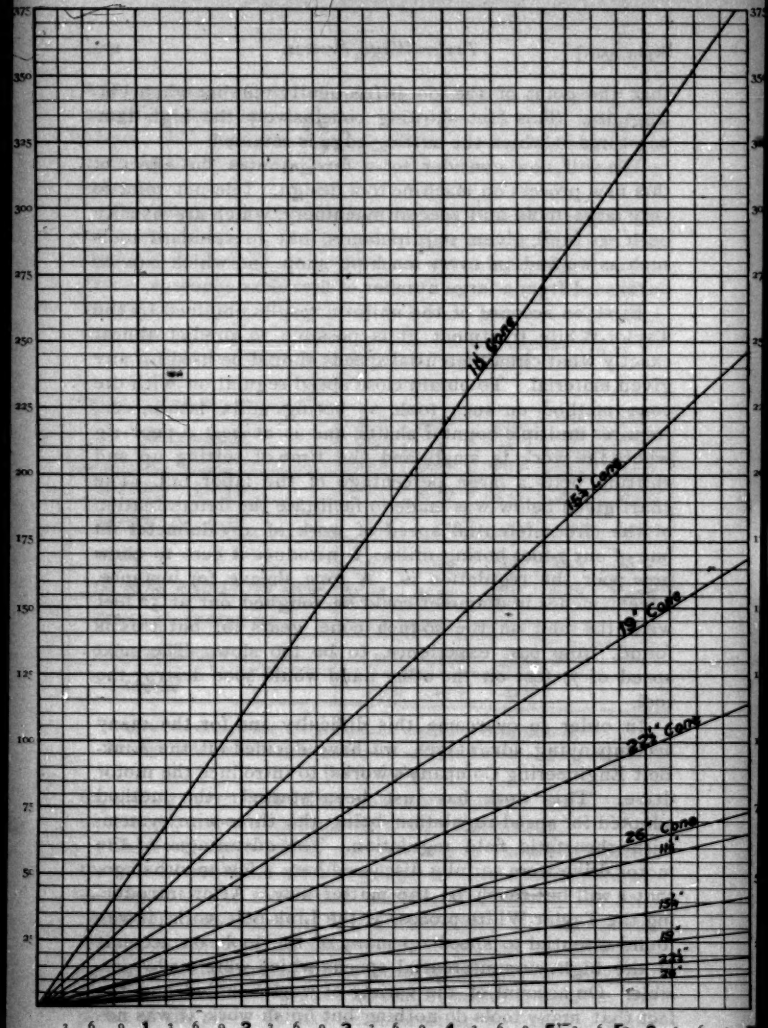
that the point of the tool is frequently red hot when cutting dry. This fact showing conclusively the high temperatures at which the cutting edge is retained.

We will now consider for a few minutes, the effect of this new process on machine tool design. I do not refer to very large tools and special machinery, which are usually built to fulfil given requirements, but to standard tools such as we find in every machine shop and which can be purchased from a large number of first-class concerns.

First, on account of the uniform results obtained by the Taylor-White treatment, it is possible to predict almost exactly what circumferential speeds should be used for any given material. To obtain close speed regulation with the cone method on such tools as boring mills, lathes, etc., requires multiple counter shafts, and is at best a poor rig where the work is small and the time of setting up and shifting belts a large percentage of the labor bill. The chart given below was made to facilitate the determination of the circumferential speed of work of any diameter on one of our 7-foot boring mills. I introduce it here to show how poor the regulation is. A rope sheave, for instance, 5 feet 0 inches in diameter could be roughed out at 52 feet with the belt on the 26-inch cone, gears in, but this is found, from past experience, to be too slow. The next speed of 77 feet on the other hand would soon destroy the tool.

In order to overcome this difficulty and for the many accompanying advantages, we have decided (at the Link-Belt Engineering Company's works) to introduce the motor drive. This work has just been started; the method adopted for speed regulation being the three-wire system, with rheostatic field regulation. The advantages of the motor drive were so fully discussed here a few months ago, that I will but touch on the matter now. After introducing the Taylor-White process at the Link-Belt works, it was found essential to speed up many of the tools on account of the high circumferential speeds which were made possible. On account of the variety of work handled and the fact that many tools do nothing but finish work, it was no

Link-Belt Engineering Company.



Scale, 1½ inches = 1 foot diameter.

Table of circumferential speed for work of any diameter. Boring mill No. 191.
August 30, 1000.

practicable to increase the line shaft speed more than 30 per cent.: the natural solution being motors; the machines becoming self-contained and permitting of any experimental work without shutting down the line.

As the machines were speeded up to obtain higher circumferential speeds, the power required to drive them idle was found to increase very rapidly, the limit of the line and engine being soon reached. An example may make this clear:

SEVEN-FOOT BORING MILL.

	Min.	Max.	Power required to drive table at max. speed. Horse-power.
Original range of table speed, .	·5	17·26	10·00
1st change, increased 25 per cent.			
2d "	·9	23·50	15·30
3d "	1·28	33·8	23·00 (approx.)

Eighteen months ago a 50 horse-power Buckeye engine furnished power to about forty of our machine tools, including three boring mills (10 feet, 7 feet, 6½ feet) our pattern shop and grinding room, the latter containing six carborundum wheels, four of which are frequently in use at one time.

The average horse-power developed has been determined frequently and averaged about 45. It required, however, about 27 horse-power to drive the line shafting and counters, thus leaving but 18 horse-power for actual work. After the new tools were in general use and the machines pushed to obtain the desired results, it soon became apparent that the power was absolutely inadequate; indicator cards from our engine frequently showed an overload of 60 per cent., and at this point we found it essential to put motors on some of our larger tools for the present, with the intention of using them entirely in the future as stated above.

Coming back to the machine tool manufacturers, it is quite remarkable how little many of them seem to know about the power required to drive their tools under varying conditions. How many builders can tell you the pressure on the tool for a given depth of cut; feed and speed for a given material on boring mills or lathes, yet how can they

expect to design the tool correctly for power and rigidity if they have not this information? Why is the "power limit" so ridiculously low on many of our small machines, the spindle speed and feeds out of all proportion for the work they are expected to do? The answer is easy, the question has never been attacked, by most manufacturers at least, by the methods so well exemplified in the Taylor-White process or the Jones ingot mold.

With a tool steel which can be counted upon to give certain results, it will be possible for the manufacturer to build machines on scientific principles, instead of guesswork; then it will be possible to work the tool to its highest efficiency, instead of finding the "power limit" far below the requirements, as is now so often the case.

I recall an experience we had a few weeks ago while investigating some small drill presses, purchased in order to complete an order containing several thousand duplicate cast iron parts. The ones finally obtained gave a maximum spindle speed of 290 revolutions. The Morse twist drill table calls for a speed of 214 revolutions per minute for a ½-inch drill in cast iron. We ran the same size drill at 290 revolutions per minute passing through a 3-inch hub in one minute and twenty seconds. We found it paid to grind up completely two twist drills in a ten-hour day on each drill press; the tool room force of course keeping the men supplied with sharp drills.

It should be understood that the above twist drills were not treated, but the same as we have been using for years. If a ½-inch drill on a 24-inch drill press can be run at the maximum speed and feed obtainable, how can we expect to run the smaller sizes efficiently, and what, I wonder, does the manufacturer expect one to use the speeds for, obtainable with the gears in? We have found it possible to double the speed of all our drill presses, but this, of course, does not help the feed.

From data obtained by Mr. Taylor, over a long period of years, it has been possible to obtain a relation between the circumferential speed, feed, depth of cut, and time element, and so derive an empirical formula, upon which data,

together with the details of any given tool, most ingenious slide rules have been formed. It is possible with these instruments (which are in practical use), to make out time cards from the blue-print and before any work has been done on the piece, showing the workman just where to put his belts and how to set his feeds and depth of cut for a given material in order to have the desired power, and at the same time remove the maximum poundage in order that the tool should last a certain pre-determined time. The time the tool should last being based on the time necessary to change the tool, and is expressed in the empirical formula above referred to. I merely mention the above facts to show how the tool designer of the future will be able to accumulate a store of information which will be the basis of all the work, and how widely the machine shop practice of the future will differ from that of the past.

"Production to the Power Limit" was the title of a most interesting article written over five years ago by Mr. Arnold, in which he strongly advocates pushing all tools to the limit of their endurance, on the principle that the quicker they are worn out, the more money they make. Although this view is now accepted by many leading machine shops, it has not been enforced, old tools which should have been scrapped years ago, being in operation. If Taylor-White process is introduced into shops of this character and worked to its very best advantage, the weaknesses of these tools will be developed at once, and they are bound to go where they belong, on the scrap pile. Probably you have all read Mr. Porter's article on, "The Radical Policy of Scrapping Expensive Machinery." This policy applies just as well to small machine tools. In the majority of our machine shops, where all of the tools are relatively small, there is just as big a field for this radical policy as in our largest establishments. The turret lathe, milling machine, gang drill, etc., are all coming into general use, and have resulted in the scrapping of many old style tools. The Taylor-White process of treating tool steel, in a like manner, will result in the scrapping of tons of stock, and just

as the last twenty years has seen the establishment of self, or air-hardening tools in all our shops, so in the next few years I think we can predict that all machine shops, who wish to keep to the front, will be using steel treated by the new process.

My remarks up to this point have dealt with the relative merits of tool steel, and the great increase in the output possible, when the Taylor-White process is used.

The question now arises, How are we to maintain this increased output throughout the shop? A person who has had little or nothing to do with machine shop management would probably think this an easy question, but it is, notwithstanding, a most difficult one. We must not judge the average conditions by those encountered in Philadelphia, where labor unions have but small control, but rather turn our attention abroad, or to our Western cities, to realize the difficulties encountered by the shop superintendent.

There is nothing new about driving machines to their power limit. I remember reading an article by Hiram Maxim on "Trade Unionism," where he quotes an old Scotch machinist, who told him when a boy, how to become a good machinist, namely, "to work the tool to the limit, to run on the belt, and always have a new tool ready to put in tool post, etc., etc." How closely is this policy followed out to day by our workmen? The average foreman is far too busy following up orders, etc., to look after the details of speed on individual machines, and no one else is in close enough touch with the work to give it the required attention. The only satisfactory solution to the problem, where there are sufficient men to justify the move, is to appoint a speed foreman, who must be a man of considerable tact, in the beginning at least, in order to maintain the good will of the men.

Production to the "tool limit" is but one of the many means to attain the end that all up-to-date concerns have in view, namely, to produce a better article at a cheaper cost. It has been well named the age of "intensified production," and extends to every branch of manufacture. Competition has become so severe, unless one makes use of every opportunity, he is soon driven to the wall.

The engineer of the present day has before him a tremendous field, the production of the best for the least money, involving a thorough knowledge of every branch of engineering, shop management, etc. The laboring man cannot stop the advance any more now than he could in the past, but as he is just as much a part of the whole, as the machine or tool steel, he should be just as carefully watched, his welfare attended to, his physical and mental conditions looked after, and, in fact, be made just as good a workman as possible. In many establishments the machinery is most carefully attended to, while the man who operates it, the keynote of the whole scheme, is ignored. The importance of this fact is now being realized by many concerns, much money being spent, money which will pay big interest, to add to the comforts and welfare of the employees. It should be clearly understood that nothing is offered in the way of a bribe or obligation, the effort being to make the surroundings such that the workmen are both physically and mentally stronger, and in a position to turn out more work unconscious to themselves. Methods like these will, I think, help the labor troubles considerably and facilitate the introduction of new ideas.

Too much stress is placed on what a machinist is paid per hour, or how long he works by the time clock. These points are of but secondary consideration, the "work rate" being the true gauge.

At the Link-Belt Works no fixed rate of wages is employed, the men being paid according to their merits. After the introduction of Taylor-White steel, it was essential to remove the piece rates from many standard operations, and in all such cases the policy of the company has been to divide the savings effected with the men. After the men knew that they would share the advantages derived from the new process, their whole attitude was different, and, in fact, what else could we expect.

In the latter part of this paper I may have seemed to digress considerably from the matter in hand, but it all tends to show how far reaching are the influences of the Taylor-White process.

In conclusion I wish to state that it was due to the courtesy of Messrs. White and Taylor that I have been able to present to you this evening the statistics and steel chips obtained at the Bethlehem Steel Company.

COMMERCIAL ALUMINUM-ZINC ALLOYS.

No alloys containing more zinc than aluminum have any specially valuable mechanical properties, even the alloy of equal parts of both. The alloy Al—2, Zn—1, reaches a tensile strength of 40,000 pounds per square inch, melts at 425 degrees centigrade, does not easily oxidize, and takes a fine finish. It closely resembles a high-carbon steel in character, and is the hardest and strongest of the Al-Zn series. Its specific gravity is 3·8. A contraction of 17 per cent. takes place during alloying. The alloy Al—3, Zn—1, is the most generally useful of the series. It is softer than the last, tensile strength, 35,000. It is not malleable, but yet not brittle, bending before breaking. Hence, castings may be straightened out. Specific gravity 3·4, contraction 14 per cent.; good castings are yielded. When made from pure metals it is equal to finest brass in the lathe and under the drill and fire. Its color is equal to that of aluminum. It is used for scale beams, astronomical instruments, light machine parts, testing machines, surgical appliances, etc. Below 25 per cent. zinc the strengths of the alloys decrease rapidly. The 15 per cent. alloy can be rolled and drawn; tensile strength 22,330 pounds per square inch.—*The Electrochemist and Metallurgist.*

A NEW METHOD OF ADULTERATING WINE.

It has recently been ascertained that a peculiar method of wine adulteration has come extensively into vogue in European wine-growing countries, and which involves the conversion by chemical means of red, into white wines.

A French chemist, in the course of certain investigations upon the constituents of the ashes of certain wines, found present therein about one-half of 1 per cent. of manganese protoxide per liter of wine. Further investigation of the subject seems to have confirmed the suspicion that the investigator had to deal with a red wine which had been treated with animal charcoal (bone-black) and potassium permanganate for the purpose of effecting its decolorization. It also was shown that this artifice had assumed large proportions among the wine producers, since the public had begun to show a preference for white wines, which consequently had increased in price.

The following method of detecting this method of adulteration has been proposed. Ten cubic centimeters of white wine should be treated with 1 to 2 cubic centimetres of caustic soda solution, followed by 1 cubic centimeter of hydrogen dioxide. When these constituents are thoroughly mixed, the liquid will instantaneously take on a mahogany-red color. In the case that hydrogen dioxide is not available, the same reaction will occur, though more slowly, by using in excess of caustic soda. W.

THE FRANKLIN INSTITUTE.

Stated Meeting, held Wednesday, June 19, 1901.

OBSTRUCTIONS TO COMMERCE AND HOW TO REMOVE THEM.

By Lewis M. Haupt, C. E.
Member of the Institute.

Commerce is the life of nations and water its principal medium of communication.

Ships are the shuttles and the ocean is the loom that weaves together the human family. Without them, portions of the earth would revert to barbarism.

The highest stages of civilization therefore demand the shortest, freest and most ample routes for commerce, but the general trend of the physical forces is toward the degradation of channels by the accumulations of detritus carried down the rivers or along the shores and deposited wherever the continuity of the stream is broken or diminished.

The mountainous tributaries with their steeper slopes carry their sediment to the main streams where the larger particles are deposited in the upper reaches, thus raising the flood plane as well as the bed of the river and building obstructing bars which must be removed by the application of science.

Although "all the rivers run into the sea, yet the sea is not full" because of those beneficient counter forces which return the waters unto the place from whence they came. There the mountains condense and reprecipitate them for a renewed attack upon the land.

Not so, however, with the eroded alluvium which is perpetually rolling down the incline to fill up the channels or deltas with dangerous obstructions.

The poet Milton has aptly said:

"Accuse not Nature, she hath done her part,
Do thou but thine."

But mind cannot dominate matter until it has first mastered her methods of operation. Man cannot change physical laws. He can merely apply them after observation and experience have demonstrated their properties. Although centuries of research have taught mankind something of these attributes, much yet remains to be discovered.

Analysis and synthesis are the handmaids of progress. Success is the climax of failures, while failures are the wrecks which serve as buoys to mark the channel to success.

Every sand bar is the effect of natural causes and it frequently possesses certain features, as to form, position, slopes, profile or magnitude which indicate the direction and nature of the forces operating to produce it, and which characteristics suggest the proper treatment for its removal.

Every break in an alluvial coast is obstructed by its submerged embankment or outer bar, either drift or delta, which rarely carries more than fifteen feet of depth at mean low water and which compels vessels to await high water and sometimes spring tides, involving delays of weeks and formerly of months, before being able to leave port with full cargoes.

Only last week, the 15th inst., the "Nordland" was obliged to leave 1,000 tons of freight on the dock at this port because of the limited draught in the channel, while vessels of 27 feet draught have declined to charter for Philadelphia.

The rise of the tide is, however, very variable, not only at one point, but at different points, depending on the configuration of the shore line. In some tideless seas it is zero, while in funnel-shaped estuaries it may oscillate as much as 60 feet. Around the British Isles the tides range from nothing at Courtown, Ireland, to 35 feet at St. Malo.

Along our Atlantic seaboard it ranges from about 2 to 10 feet, while in the Gulf its mean oscillation is only 14 inches. In the great inland seas of the Baltic and Mediterranean it is about 1 foot, so that there are many ports where additional depths must be provided to meet the growing demands of commerce.

Waves also constitute an obstruction when too tumul-

tuous, occasionally involving the loss of vessel, cargo and crew.

Although sand bars are the most general and most dangerous obstacles, because submerged, there are others which are quite as effective even though visible. These are the peninsulas, isthmuses and continents which intercept the trunk lines of trade and require large détours to be made, involving loss of revenue with no corresponding benefit.

The most striking example of this class of obstacles on the globe is the continent of South America, which lies east of the meridian of Charleston and therefore separates our Atlantic and Pacific coast trade by 15,000 miles more or less and requires the circumnavigation of the continent because of the Isthmian barrier. The piercing of this narrow strip of land by a deep-draught waterway would obliterate the continental obstruction and at the same time bring all the habitable sections of the earth into much closer contact, thus contributing more than by any other possible work to cement the nations of mankind and to advance civilization and Christianity.

Other lesser obstructions to our coastwise commerce are to be found in the Peninsula of Florida, the Maryland-Virginia Peninsula and those of New Jersey and Massachusetts; while the overland portages separating the Ohio River from Lake Erie and the Mississippi from Lake Michigan are barriers which demand and are receiving public attention.

The economic interests of this country will soon awaken to the necessity of systematically developing trunk line water routes extending from the Atlantic seaboard through the Great Lakes to the Mississippi and Gulf, and the development of an incomparable coastwise system of canals for our internal commerce. This is one of the factors which should be engrafted on the proposed new Department of Commerce and Public Works.

Another obstacle to the growth of commerce is tolls, and in this respect this city is particularly unfortunate in having three artificial waterways of limited capacity still main-

tained as toll gates, to levy tribute upon the raw materials required for her manufactures, while her channel to the sea is not yet sufficient to enable the deepest ocean liners to reach her wharves in safety, fully laden.

The price of coal or the absence of stations where it may be secured at any price, constitutes another impediment to the interchange of trade. This defect may be in part ameliorated by increasing the navigability of our rivers and the opening of their mouths for larger bulk movements and cheaper deliveries of this prime necessity at remote stations. A very large tonnage might be placed on the Pacific stations, from the Appalachian fields if the Isthmian canal were available, thus creating new markets. Such are some of the physical obstacles which it is the province of man to remove or reduce to their lowest terms, and it is important in this connection to trace briefly the efforts which have been made in this country to secure these results.

INTERNAL IMPROVEMENT DUE TO PRIVATE CAPITAL.

Our internal waterways and most of the railways of the past century were largely the product of private capital expended by corporations holding State charters. In this way the Dismal Swamp, the Union, James River and Kanawha, the Erie, the Delaware and Raritan, the Schuylkill Navigation, the Saint Mary's "Falls," the Louisville, the Hudson, the Juniata, the Illinois and Michigan, the Monongahela Navigation, and many other canals and waterways were built and a large traffic developed upon business principles. Many of these were subsequently acquired by the Government, and made free. Nearly the entire railroad mileage of the United States was constructed in the same way by private funds.

As early as 1790 Congress ratified certain State acts authorizing public improvements by private companies. In 1800 Georgia was authorized to collect a duty of 3 pence per ton for clearing the Savannah River. Two years later, $30,000 were applied to lighting the Delaware, and in 1806 funds for further improvements were authorized to be

collected by the Port Wardens of Philadelphia by levying a duty of 4 cents per ton on commerce.

In 1816 Virginia incorporated a company to improve the James River. On the admission of Alabama, in 1819, an act was passed authorizing the appropriation of 5 per cent. of the net proceeds of land sales for roads, canals and rivers. The first appropriation for the survey of the Mississippi River was $9,500, made in 1820.

In 1822 the Secretary of the Treasury was authorized to supervise the construction of a sea wall at Smutty Nose, and a breakwater in Delaware Bay.

The next year the authority to make surveys was vested in the President, and in 1824 his powers were extended to employ skillful civil engineers and to detail officers of the Corps of Engineers to make surveys "of such roads and canals as he may deem of national importance," and also to provide the necessary plant.

From 1826 to 1839, through the Adams and Jackson administrations, the policy of the Government was to collect all appropriations for public works affecting interstate commerce into general bills, but from the latter date until 1867 it was relegated chiefly to the States, with the exception of 1844 and 1852, when general bills were passed, the latter being for Western rivers. In 1867 the general bills were resumed, and have continued to be the recognized policy of the Government, although of late years it has been a difficult matter to pass the appropriations for rivers and harbors during the short sessions of Congress.

Thus has grown up the present system of detailing military engineers to conduct our public works and authorizing them to employ civil engineers as their assistants, subject to suspension in case of the failure of the bills.

Between 1822 and 1866 inclusive, the expenditures were	$14,990,170
Between 1867 and 1900 inclusive, the expenditures were	332,487,627
Making a total of	$347,477,797

Until recently it has been distributed very generally over disconnected improvements, and it may not be out of order to review some of these works with reference to their effects on commerce.

During this time a large amount of experience has been obtained, however, but its recipients are transferred under our system to other points where there may be no opportunity to apply the knowledge thus gained because of the different conditions prevailing.

The failure of the appropriations and the transient assignments of those in charge may therefore be regarded as additional obstructions to the securing of deep channels for our ships.

It should be observed, in passing, as a distinguished Senator recently remarked, that "the currents of the ocean depositing sand along the coast throughout the years and centuries pursued their way in defiance of our edicts and laws," thus showing the futility of human efforts to utilize physical forces when these latter are not fully understood.

The Senator recognized the fact that the bars are due to ocean currents, but this is not all; he might have added "wave action," angle of approach, configuration of shore line, tides, winds and many other elements which combine to make every inlet a special problem. For example, the ports of Charleston and Port Royal in South Carolina, although adjacent, are as dissimilar in topographic features and results as can well be imagined, and for good reasons. Charleston is an excellent type of a *drift and wave bar* formed from beach sand driven in a prevailing direction by the resultant of the dynamic forces of the sea and the main ship channel, across the bar, which is cut out by the ebb currents, is located about 7 miles south of the gorge or opening into the bay. The natural depths at this point were about 15 feet in 1777, and 12 feet a century later at mean low water, while at Port Royal they are over 21 feet, and the bar channel lies directly in front of the gorge, where it has remained for over 125 years without deterioration or protecting works.

SUBMERGED JETTIES.

In entering extensively into this class of work by the use of jetties, a Government officer formulated the conditions to be fulfilled in them in 1879 as follows:

(1) They should not impede the inflow to such an extent as to prevent the tidal basin being filled, as now at every influx of the tidal wave.

(2) They should control the outflow to such a degree and in such a manner that a channel of the required depth will be maintained through the bar.

(3) They should not to any considerable extent cause a movement seaward of the main body of the bar. In brief, the works should be designed to admit the flood tide freely, confine the ebb tide to a single channel and prevent bar advance.

To secure these effects it was recommended that two convergent jetties be built having their inner or shore ends submerged and their outer or bar ends built to high water, and the cost was estimated to vary from $1,800,000 to $3,000,000 for a 21-foot channel. The mode of construction was to be "very gradual in its progress, to admit of such modifications in the lengths and heights of the jetties as experience shall dictate."

"High-tide jetties are not recommended, as their effect would be to form new bars outside of the present one, requiring jetty extensions." These general conclusions were considered so sound that the works at numerous South Atlantic, Gulf and Pacific harbors were based upon the submerged jetty system, but one by one they have been abandoned and the jetties raised; first, to mean low water, then to mid-tide and finally to above high water, so that the Charleston entrance is the only extensive illustration remaining of this type of construction and it may be reviewed to advantage for its experience.*

Work on the jetties was begun in 1879, and in 1881 some experimental dredging was done on the bar, which was said to be so exceptionally hard that the cutters did not work, so it was abandoned and jetty work continued.

By 1888, or after nine years of "very gradual" progress and experiment, the greatest available depth between the jetties was but 11½ feet and the officer in charge recom-

* See "Harbor Studies," Engineers' Club of Philadelphia, January, 1886.

mended a return to dredging at a cost of $100,000, as well as the building up of the jetties to a greater height. A Board of Engineers in reporting on this, suggested that "the two jetties should be brought to mean low water level." * * * "Above this * * * construction should take place tentatively." The height mentioned is merely for use as the basis of an estimate. The dredging of the main channel to a depth of 15 feet and 350 feet wide is recommended.

In 1890 it was stated that "the action of the jetties is to be assisted by dredging" and during the year 56,626 cubic yards were removed. This was followed in 1891 by the dredging of 47,626 yards. It was also estimated that if the jetties were brought up to 3 feet above low water, throughout, the cost would be $5,334,500. But what matters the cost if results are attained?

Up to June, 1891, over $1,800,000 had been expended in the thirteen years of work and a depth of 12 feet had not then been secured in the proposed new channel. After more than twenty years the report for 1900 states that the total cost to June 30, 1899, was $4,037,256.70 and that the channel depth was not less than 20 feet. The submerged jetties were completed in 1897. During the following year dredging was continued excepting for three months, while the dredge was being repaired. The depths varied from 19·3 feet to 20·1. The total amount of material removed that year was 253,401 cubic yards. A new and larger dredge was authorized, to cost not more than $150,000 and $60,000 was the estimated cost of maintenance. The map accompanying this report shows the crest of a new bar lying in the open ocean and about ¾ of a mile beyond the end of the completed jetties through which it is necessary to maintain a channel by dredging. It is therefore manifest that these submerged jetties have not fulfilled the requirements of scouring out and maintaining a channel, nor of preventing the seaward advance of the bar and that the expenditures and operations of the past twenty-two years have been beneficial mainly in the experience furnished, for if a channel is to be secured and maintained

by dredging in the open ocean, it would seem to have been better to have attacked the bar in its original position and to have saved the $4,000,000 put in the jetties.

Since the inauguration of the general bill for rivers and harbors in 1867 the amounts have increased rapidly from year to year until they have in themselves become an obstruction to commerce from their very magnitude, as was instanced at the close of the last session when the bill was "talked to death."

ANNUAL INCREASE OF EXPENSES.

Between 1867 and 1879 the total expenses were $53,763,068·57, or about $4,480,000 per annum, while after the theory of the submerged jetty was extensively introduced and twin jetties were built under the tentative methods recommended the total expenditures have aggregated for rivers and harbors $278,724,558.64 up to and including 1900, or an average of about $12,670,000 per year.

The annual expenditures jumped from $3,791,000 in 1878 to over $8,267,000 the next year and have been increasing at a rapid ratio until they exceeded $20,000,000 in 1898, due in some measure to the increasing cost of maintenance on exposed bars by dredging. Although the total of nearly $350,000,000 expended since 1822 in this class of improvements may seem large, it is much less than that spent by countries which are smaller than the state of Texas, but their methods are such as to secure more permanent results. It will thus appear that our system is at fault and becomes, as has been stated already, an obstruction to commerce, since its very magnitude makes it a menace to the success of party control. At the last session of Congress it was stated that the patronage in the works recommended and in progress on the river and harbor bill amounted to about $300,000,000, thus placing the grave responsibility upon Congress of reducing it almost arbitrarily to some reasonable sum in order to maintain much needed channels to the sea. So much for the policy and various obstructions which have been suggested as impediments to our commercial development.

Let us now turn to a few illustrations of methods which have been applied to create open channels and note the results. The ordinary methods in vogue were by dredging; by hightide jetties in pairs; by submerged jetties and by a single jetty, to which may now be added the single, curved or "reaction breakwater" and the use of dynamite, without dredging or auxiliary works.

DREDGING.

At several points dredging has been relied upon to deepen the approaches to the ports. The most successful illustrations of this are at the Mersey Bar, Liverpool, and at Gedney's channel, New York. At Mobile, Pensacola, Southwest Pass and many other points it has not been so satisfactory, since the gain in depths have not been permanent and are expensive to maintain, as the following extracts from the official reports will show.

PENSACOLA HARBOR.

For many years Pensacola had a natural depth of 23 feet, which was greater than that of any of the Gulf ports. It was readily entered by sailing vessels, but the growth of the inner middle ground so reduced the channel depths that in 1881 a project was recommended for a cut 300 feet wide and 24 feet deep at low water, to be secured and maintained by dredging.

During the subsequent twelve years this depth was secured several times, but not the width. The report states: "The relief of the commerce of the port by dredging under this project, while it served a purpose, proved to be very unsatisfactory, as, owing to the conditions, mainly the location of the channel with reference to the middle ground, rapid and constant filling of the channel occurred."

In 1891 the project of 1881 was abandoned, and it was proposed to open a new channel across Caucus Shoals by means of jetties, and by dredging if necessary. In 1895 a special board was appointed to reconsider the plans of 1891. It adhered to the location of the 1891 channel. By this date the depth had shoaled to 21 feet. Another Board of

Revision recommended that a dredge be built, and that until a channel be opened by dredging, no jetties should be built for its maintenance.

In 1899 the plans were modified to provide for a 30-foot channel.

The instability of the dredged channel is well illustrated by the following tabulated statement taken from the official report of 1900:

Date.	CHANNEL.		Cubic Yards Removed.	Remarks.
	Projected.	Secured.		
				Estimated cost, $150,000.
1881	24 x 300			Contract let at 40 cents per cubic yard.
1882-3			8,406	Contract let at 79⅞ cents per cubic yard.
1883-4			24,966	Dredge hire, $333.33 per day.
1884-5			53,369	
1885-6		24 x 120	55,355	
1891-2	26 x 300		14,151	
1893, Aug.		24 x 225		
1895, Dec.		21—		Dredged between October '95, July '96.
1895, Dec.		24 x 120		
1896, July	30 x 300	24 x 80		
1897, July		23·4 x 85	300,424	R. Moore dredged April 1897—July '97.
1898, Feb.		22·8 x 100	255,029	R. Moore dredged Feb. 1898—July 27, '98.
1898, July		24—		
1899, June		25 8—	334,405·5	R. Moore dredged Feb. 8,'99—June 30,'99.
1900, June		28 7—	479,087 9	R. Moore dredged during fiscal yr., 1900.

There were $215,000 appropriated between 1878 and 1886 at which date the estimated cost of completing the 24-foot channel was $40,000. The tides failed to maintain the dredged channel.

In 1888 it was stated that $60,000 would be required for completion, making the total cost of the work $275,000. This estimate was increased in 1890 by $81,000, bringing it up to $356,000.

In 1891 two jetties, 3,500 feet apart, were proposed at an estimated cost of $1,830,000, while the estimate for a 24-foot

channel by dredging was $190,000, with $30,000 for maintenance. It was, therefore, recommended that dredging be continued.

In the 1900 report the available depth is given as 28·7 feet, although the central depth had been dredged to 31·2, showing a shoaling on this line of 2·5 feet, and on the range 75 feet east of this, the loss of depths was 4 feet; while on that 75 feet to the west it was 2 feet. To complete the project of 1891 would require the dredging of 350,000 cubic yards.

To secure 30 feet in front of the city would require the removal of 4,985,000 cubic yards, estimated, at 16 cents, to cost with incidentals $825,000 by contract; but it is recommended that the Government build a dredge and operate it by day's labor as "by far the most economical." The amount estimated for the completion of the existing project is $683,200.

The expenditures up to June 30, 1899, were	$547,161 32
The expenditures for the fiscal year 1900, were	98,846 64
	$646,007 96

On January 6, 1900, the dredging contract ceased with a depth of 31·2 feet, which had shoaled by June 30th to 28·7 feet.

These statements serve to illustrate the increasing costs of creating and the inability to maintain the requisite channels by dredging, for it appears that at no time has the full width been obtained, and that the depths, although occasionally exceeded, have rapidly shoaled to less than those desired for deep-draught vessels. The filling in 1900 was at the ratio of about 5 feet per annum along the axis of the cut, while the cost of the work was nearly $100,000, and yet about 480,000 cubic yards were dredged out. Still the channel is not self-sustaining. To maintain it would evidently require the removal of a much larger volume annually at increased cost, so that it would seem to be more nearly correct to figure upon over $100,000 per annum to keep the cut open to its full depth of 30 feet, independently of the width. This is $3,333,333, if capitalized at 3 per cent. It does not

give much promise as to economy nor guarantee as to permanency of channel dimensions. It is believed that a single jetty at this entrance would control the littoral drift and secure the channel at much less ultimate cost than by dredging.

A pilot of over thirty years' experience at this port stated that "there must be a breakwater to give direction to the current." To this all the pilots agree.

MOBILE HARBOR.

The importance of improving this port led to the appropriation of $10,000 as early as 1826 and additional amounts in subsequent years aggregating $207,000 up to 1869, when the State Legislature created a harbor commission and bonds were issued by Mobile County for the removal of obstructions. In 1872 a Government Board of Engineers decided that the plans proposed by the State Board would be detrimental to the work then in progress by the United States which was to dredge a channel 9 miles long and 13 feet deep from the inner harbor to the sea.

Various estimates were made as to the cost of creating the channel which ranged from $91,208 in 1866 to over $2,000,000 in 1878; the latter being for a channel 21 feet deep and 200 feet in width. The unit prices in 1870 were 50 cents per cubic yard and in 1875 they had dropped to 17.

In 1873 the State Board was abolished after expending $72,025.95. The Mobile Breakwater Company was chartered by the legislature and began operations in 1877, at which date there had been dredged from the channel 1,303,581 yards—at a total cost of $390,169.55. The dredging averaged 28 cents. By 1884 the cost had fallen to 9 cents per yard by contract.

Between February 19, 1881, and April 25, 1887, there were removed 5,973,919 cubic yards on the 17-foot project and it is reported that there has been a refilling "of about 1,300,000 yards or at an average rate of 216,660 cubic yards per year;" 700,000 yards then remained to be removed to complete the project, estimated to cost $84,000, but the channel was "altogether too narrow and should be widened

at least 100 feet, which will require the removal of 3,000,000 cubic yards at a cost of about $360,000." The progressive stages of the channel may be shown from the following extracts from the reports of the Chief of Engineers of 1900.

The first project for a 10-foot channel was covered by appropriation of $228,830.68 between 1826 and 1857.

The second project for a 13-foot depth and 300 feet wide, between 1870 and 1876 secured $401,000 from the Treasury.

The third, for a 17-foot channel 200 feet wide, covered the period from 1880 to 1888, when it was enlarged before completion to one 23 feet deep and 280 feet wide. Between 1878 and 1886, $750,000 more were appropriated, and the fourth project, from 1888 to 1898, has secured $2,268,800 for dredging, while the fifth state of the improvement was begun June, 1899, and is now in progress under appropriations for continuing contracts of $600,000

Making the total appropriations from 1826 to date . . .	$4,248,630 68
While it is estimated that to complete, will cost	1,040,000 00
	$5,288,630 86

and it is said that at the beginning of the fiscal year 1899–00, there was a navigable channel of 19 to 22 feet, but available for vessels drawing 22·5 feet "on account of the softness of the material which had filled in." During the year 4,273,381 cubic yards were removed, resulting in a channel of from 40 to 150 feet wide "of over 12 miles dredged to a depth of 25 feet." The detailed report states that the condition of the channel on June 30, 1900, showed 14 miles having less than 23 feet; 12 miles having less than 22 feet, 10·5 miles with less than 21 feet and 2 miles of less than 20 feet.

From this it would appear that although over 12 miles were dredged to 25 feet it has all shoaled to 22 feet and a portion of it to 19 feet. This constant tendency to shoal is further illustrated by the previous reports, for in 1893, the central depth was dredged to 23·86 feet, but shoaled to 19·6 feet; in 1894, it was dredged to 25·2 feet, but shoaled to 19·6 feet; in 1895, it was dredged to 26·5 feet, but shoaled to 23·5 feet; in 1896, the contract was reported completed, depth,

23·0; but by 1897 considerable fill had taken place and 20 miles of the channel had less than the contract depth. Sixty thousand dollars were appropriated for maintenance with resulting depths of 20 to 23 feet, with subsequent further filling to reduce depths to 20 to 22·5 feet and $100,000 more applied to maintenance with a renewal of the continuing appropriation.

From the above condensation it would seem that the annual expenditure of $60,000 is insufficient to maintain the 23-foot channel, about 33 miles in length, through Mobile Bay and that measures should be taken to protect the cut from the drift by some permanent regulating works. If it should cost $100,000 a year to maintain a channel, it would no doubt be expedient to expend $2,000,000 in protection work to make it more permanent. It seems hardly necessary to add that this mobile material, with its suggestive name, is dumped into a mobile bay to be carried by the automobile tides and winds back into the Mobile channel.

It is suggestive of Tennyson's "brook" which "goes on forever."

THE TWIN JETTIES SYSTEM.

One of the most suggestive examples of the effort to secure depths by two jetties, is that at Galveston, on the Gulf coast, where various plans were tried and modified from time to time. Here, however, the largely increased cost is found to be due to the rapid advance of the bar gulfward, in consequence of the building of the leeward jetty first, after the gabionades used for the windward or north jetty had been found useless and abandoned. This instructive experience is best stated by extracts from the official reports as follows:

"On the north side of the island in front of the city of Galveston, depths of 35 feet are found in a narrow channel. This area of 270 acres forms Galveston Harbor."*

Access to it was obstructed by an outer bar whose crest, in 1869, was about 3 miles from the inlet and whose low

*See report of a Board of U. S. Engineers, January 21, 1886.

water depth was about 12 feet. An inner bar also existed, having depths varying from 9½ to 15 feet.

To remove this the city of Galveston constructed a wooden jetty nearly a mile in length, in 1870, which maintained the depth so long as it lasted, but between the teredo and storms, it was of few years' duration.

The Government project for a 12-foot navigation estimated to cost $1,300,000, by two jetties, was not adopted. The first appropriation of $25,000 was made July 11, 1870, followed by one of $20,000 the next year, to dredge a channel 80 feet wide and 12 feet deep, across the inner bar.

In the year 1871, the officer in charge reported, "the work is not susceptible of permanent completion," and on July 20, 1872, that the dredger and plant "were not needed or worked during the year, due to the good effect produced by the jetty constructed by the city of Galveston."

In 1874, a board of engineers recommended a plan of two parallel and submerged jetties extending outward into the Gulf, over 2½ miles apart and having a total length of 37,000 feet, or over 7 miles; estimated to cost $1,759,401.85, but work was delayed until April 14, 1877, when the north jetty, built of gabions, was commenced and by January 1, 1880, it was placed for nearly 2 miles. An examination made that year revealed the astounding fact that "the gabionade had essentially gone down below the original bottom, consequently it could not serve to direct or confine the currents."

These gabions, which were 6 feet high, were found standing in a trench from 4 to 7 feet deep and "contrary to expectations, they did not become covered with sand, but remained standing in a trench entirely uncovered."

This result was due to the fact of their being submerged and hence subject to cross-currents and overfall from both flood and ebb tides. It ultimately led to the raising of the jetties to above high water and the substitution of rip-rap of stone covered with heavy blocks, as well as other revisions of plans which it was stated offered "every guarantee of success."* At that date, 1880, the report says: "The

* Report of Chief of Engineers, 1880, p. 1205.

suggestion as to details of construction are tentative only." * * * "The south jetty should incline more to the north so as to contract the opening between the two at their outer ends, but still remaining more than 2 miles apart." * * * "It has always been assumed that the Galveston jetties are to be submerged, but to what depth can only be determined by results. * * * Should an average height of 5 feet above the sand bottom prove sufficient, it seems probable they can be constructed for $40 per lineal foot." The estimated cost for a 25 foot channel by jetties was then $1,825,813, yet nearly $9,000,000 have been expended to date. Under this revised project the work on the buried north jetty was discontinued and that on the submerged south jetty pushed as rapidly as possible, so that by June 20, 1882, nearly 4 miles were laid on the bottom and 2 miles of the second course was in place. It was then reported that the results were not such as were to be expected and the depth on the bar was 11½ feet, while there was a rapid advance of the bar gulfward.

The report of 1884 says, no benefit has resulted as yet to navigation and the outer bar movement still continues. Channels dredged on the bar are rapidly filled up by the drift of sand from the north. "The north jetty is absolutely required if it is expected to secure deep water." The civil assistant engineer reiterated this recommendation in his successive reports, until he was surprised to find himself relieved by orders from Washington without stating the cause.

The appropriation bill having failed in 1883, the city of Galveston again came to the rescue by subscribing $100,000 to continue work, and requested Captain Eads to submit a guaranteed proposition to create a deep channel, which he did at an estimated cost of $7,750,000 for 30 feet depth. His efforts to secure this contract, however, were unavailing, as it was represented that under Government control and the expenditure of $700,000, material increase in depths, amounting probably to 5 or 6 feet, could be obtained in two seasons. Experiments were, therefore, continued, and after building several miles of extra jetty work, made necessary by the

advance of the bar, without improved depths, the plans were again revised; the high stone jetties suggested by Eads were adopted, and the estimates raised to $7,00,000, "provided the money is freely supplied;" but still the jetties were to be 7,000 feet apart at their outer ends, and not as Captain Eads had proposed, "not over 2,000 feet." Work on the south jetty was continued, notwithstanding the frequent warnings and reports upon the injuries resulting from its extension.

In 1889 the writer urged upon Congress the necessity of building a north jetty, but in vain. Up to June 30, 1892, the south jetty had been extended about 5 miles (26,923 feet), and was "then within 5,400 feet of the outer 12-foot contour." A survey showed a depth of 13½ feet at mean low tide in the outer bar channel. By June 30, 1893, the jetty reached the crest of the outer bar, after being extended 8,000 feet. This would make the bar advance over a half mile during the year. The north jetty was not commenced until April, 1893, so that the drifting sands were allowed to dam up the channel by the jetty placed to leeward, and to feed the bar, pushing it seaward and adding greatly to the length and expense of the work, with no increase of bar depths.

No sooner was the north jetty started than improved depths were manifest; for the survey of June, 1893, showed 14 feet, an increase of 9 inches with only about 1,500 feet of jetty completed and 2,100 feet of sill or uncompleted work. Thus the predictions and recommendations of the assistant engineer as to the utility of the north jetty placed to windward of the channel were immediately verified. The appropriations to 1893 were $4,828,000, and the gain in depth 2 feet in the twenty-four years.

The report for 1895 states that up to June 30th the north jetty had been advanced to a total length of 22,500 feet, or over 4 miles, and that it was 4,900 feet further to the 30-foot outer contour. Also, "that a marked change has taken place in the outer bar due to the rapid extension of the north jetty. The 12-foot contour has entirely disappeared, the inner 18-foot curve has advanced 5,400 feet into

the Gulf, while the corresponding advance of the outer 18-foot curve has been 1,800 feet."

The new channel has a least depth of 17¾ feet, where last year the depth was 12¾ feet, a gain of 5 feet in 12 months. The southeast channel deepened 1¾ feet during the year.

This gain of 5 feet is explained in another part of the report, where it is stated that "Dredging was commenced on April 11, 1895, and up to the close of the year (June 30th, ten weeks) 68,071 cubic yards of material had been removed." so that it is not correct to infer that the deepening was due to the scour of the tides as might be implied, but to the interception of the drift by the north jetty and the removal by the dredge of a part of the bar deposit, which was not permanent, since no channel exists in this locality to-day. Thus a quarter of a century had passed in experimenting with gabionades, low or submerged jetties located too far apart, a high-tide jetty built on the wrong side of the channel, and finally two high jetties still too remote to produce scour, until at last the one placed to windward of the channel arrested the sand movements, in part, and enabled the dredges to deepen temporarily the cut across the bar. The position of this new artificial channel is not fixed nor is it straight, as was expected, but in consequence of the constant wave action on the outer slope of the bar, it is being driven to leeward and crosses the line of the south jetty produced, making a curved channel in conformity with the law of currents in the open sea.

It merely remains to state in summing up this instructive example, that in 1900 it was reported that the

"South jetty was considered to have been complete

on February 14, 1897, when it was	35,603	feet long,
and the north jetty on January 29, 1898	25,907	" "
making a total length of	61,510	" "

or 11·65 miles, at a cost of $8,251,156, or $134 per lineal foot of jetty ($717,500 per mile);" and of these 11¼ miles, it is believed by the writer that under the original condition of the bar 8 miles could have been dispensed with at a saving of nearly $5,000,000 and with far better results.

The jetties have not secured the channel by tidal scour,

but the increased depths have been obtained by the aid of hydraulic dredging and the interception of the drift. During the year (1899–1900) 164,776 cubic yards were removed from the outer and inner bar channel. The total cost to June 30, 1900, is reported to be $8,385,079.11 and $50,000 is recommended for maintenance.*

CUMBERLAND SOUND.

The most pronounced failure to secure results by a pair of jetties, however, is that at Cumberland Sound, Ga., where the prevailing littoral drift is to the southward and where the first jetty was built on the south or far side of the channel, thus damming it up by the intercepted sand and pushing the bar to sea. At a later day a north jetty was partially built, but the two resulted in so complete a closure of the entrance that an emergency appropriation was made by

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*Local engineers in charge of operations:

Major	M. D. McAlester	1868
"	C. W. Howell	1871–'80
"	M. S. Mansfield	1880–'86
"	O. H. Ernst	1886–'90
"	C. J. Allen	1890–'93
"	A. M. Miller	1893–'97
"	J. B. Quinn	1897–'98
"	C. S. Riché	1898

Total appropriation to January 30, 1892, $2,712,843
Additional Galveston, 100,000
Depth 13½ feet $2,812,843
(Total January 30, 1898, $8,251,166.47)
(Total January 30, 1900, 8,385,079.00)

BOARDS OF ENGINEERS.

1874 (p. 730) Gen. Z. B. Tower, H. G. Wright, Jno. Newton, Gabions.
1879 " " Jno. Newton, Q. A. Gillmore, Mattress
1880 (1221) " " " " " " Stone or concrete.
1886 (1297) Col. Duane, H. L. Abbot, C. B. Comstock, built up jetties and dredging.
1889 H. M. Robert, Gillespie and J. A. Smith, deep-water harbor.

Average expenditure for maintenance between 1897–1900 $157,905 per annum, since the jetties were reported as completed. This sum capitalized at 3 per cent. would represent $5,263,500 which would be more than double the cost of the single curved breakwater recommended by the civil assistant engineer Mr. Ripley in 1883.

Congress to remove the obstructions to commerce. This was after about 20 years of experiment and the appropriation of $1,787,500. In fact the channel was driven across the south jetty and it became necessary to remove a part of the same to admit light draught vessels and to dredge on the outer bar to keep it open. The crossing is now about a half mile south of the south jetty, while large sums are being expended on these obstructions to bring them to high water instead of improving the present inadequate channel which could be done quite reasonably.

THE REACTION BREAKWATER.

After prolonged research as to the action of the natural forces in building bars and maintaining channels a system has been evolved whereby the natural agencies might be employed to deepen the water by confining the ebb discharge to a limited section of the bar from which the drifting sand is excluded by an impassable barrier of such form as to cause the currents to scour by reaction. This method has been sufficiently demonstrated by the partial construction of a breakwater, detached from the shore at Aransas Pass, Texas, where the feeble tides of only about 14 inches have steadily increased the depth from about 6 to 15 feet in the shallowest part of the bar and to 25 feet and over along that portion which was protected by the completed part of the structure. This was secured without dredging and at a cost of about one-eighth of the estimated expense of obtaining a 20-foot channel by two jetties and dredging. As these facts are officially reported as to cost and results they indicate that under these unusually unfavorable circumstances the method has been thus far signally successful, yet although it has been submitted to the Executive Department of the Government having sole jurisdiction over this class of improvements, at numerous times during the past fourteen years it has invariably been rejected as of "no value," * * * "purely theoretical," * * * "fallacious," * * * "fatally defective," * * * or "lacking in novelty;" and although the work done at Aransas Pass has been accepted by the Government, after

being condemned as valueless, it is now proposed to embody it in the twin jetty plan as a substantial part thereof without compensation. This change would prevent the completion of the demonstration of its efficiency and compel the Government to secure the channel by recourse to dredging with constant expense for maintenance,—all of which are unnecessary and will prove injurious to this tidal entrance.

The creation and maintenance of an *esprit de corps* may be both useful and valuable to its members, but if it should be carried so far as to condemn and obliterate a system of improvements which experience has thus far demonstrated to be a complete success in solving the problem of creating and maintaining adequate commercial channels at a minimum cost, it would then become an obstruction to commerce and should be restricted to its normal service of military operation, for which the training at West Point is eminently adapted.

THE GREATEST POWER STATION.

Scientific American gives the following data respecting the equipment of the new electrical plant now in course of erection by the Metropolitan Elevated Railway of New York, viz.:

* * * * *

"The great power house, 200 feet in width by 400 feet in length, will be the largest in existence, and its compound engines will, we believe, without exception, be the largest single steam units to be found anywhere in service on land. The normal capacity of the power station will be 65,000 horse-power, and the maximum capacity about 100,000 horse-power. The steam plant will be made up of eight compound engines, which will be capable of running under a continuous load of 12,000 horse-power each. These engines are of an entirely new type, and they are placed in pairs on each end of a shaft which carries a Westinghouse generator with a revolving field 32 feet in diameter and weighing 185 tons. The chief novelty of the engines consists in the fact that the high and low pressure cylinders are placed at 90°, the high-pressure being horizontal and the low-pressure vertical. As there are two engines to each shaft, the turning moment is perfectly even, so much so that the customary flywheel is dispensed with, its place being taken by the heavy revolving field of the generator. The high-pressure cylinders are 44 inches and the low-pressure cylinders 60 inches in diameter, the common stroke being 88 inches. To find engines that will compare with these in size, we must refer to the engine rooms of some of the largest ocean steamships. The most powerful marine engines are those of the "Deutschland;" each quadruple expansion engine on this ship has indicated in twenty-four hours as high as 18,500 horse-power, or 50 per cent. more than the maximum capacity of the engines above described."

ELECTRICAL SECTION.

Stated Meeting, held Thursday, March 21, 1901.

SECONDARY REACTIONS IN ELECTROLYSIS.

By Prof. Joseph W. Richards,
Member of the Institute.

To be a thorough electrochemist or electrometallurgist, one should understand thoroughly electrolysis, and this is best attained by a study of secondary reactions.

To understand secondary reactions thoroughly, requires a considerable knowledge of chemistry. For this study, it is better that the student should approach it from the chemical side; that he be primarily a chemist who has added to his chemistry a knowledge of electricity, rather than the reverse.

Very, very much is unknown in this field. Some of the best known phenomena are differently explained by careful reasoners, and very little is so firmly established as to be even reasonably safe from overthrow. Many phenomena classed by one as secondary are referred to by another as primary, and *vice versa*.

The main object of this paper will be to state some of the laws of primary electrolysis and secondary reactions, and then to attempt a classification of the latter and to discuss several examples under each heading, by way of illustration and suggestion.

Using Faraday's notation throughout, I would offer the following definitions:

Primary electrolysis is the action of the current whereby it directs the ions towards the electrodes and liberates them *as ions* at the electrodes.

Secondary reactions are such reactions of the ions upon themselves, the electrodes or the electrolyte, whereby substances other than the ions come into existence at the electrodes.

The rate at which primary electrolysis takes place is

largely dependent, in solution, on the rate of diffusion in the solvent of the substance being decomposed. The rate at which secondary reactions upon the electrolyte can occur is similarly largely dependent on the rate of diffusion of the secondary products in the solution.

The work done during electrolysis is of two kinds; first, the work done in overcoming the ohmic resistance of the bath; second, the work done which is rendered latent as chemical energy. To these might be added the energy concerned in the Peltier effect, but this is in general so small, and known accurately in such a small number of cases, that I have omitted it from the subsequent discussion.

If we let R^e be the ohmic resistance of the electrolyte, that is, the resistance of the electrolyte as measured with an alternating current, and V^e the voltage necessary to overcome this resistance, for any number of ampères A, then

$$V^e = R^e \times A$$

If we call V^d the voltage necessary to furnish the energy rendered latent as chemical energy, we then have

total voltage $= V = V^e + V^d = (R^e \times A) + V^d$.

and the total energy required in watts, is

$$W = V \times A.$$

of which $V^e \times A$

appears as heat in the electrolyte

and $V^d \times A$

is rendered latent as chemical energy.

The energy which is rendered latent as chemical energy includes not only the chemical energy expended in the primary electrolysis, but also the energy expended in secondary reactions. That expended in primary electrolysis is positive, in the case of exothermic compounds, and may be negative when endothermic compounds are decomposed. The energy of the secondary reactions, that is, their algebraic sum, is usually positive, and hence usually assists the current instead of calling upon it for energy; in some few

cases this energy is negative, absorbing heat, and in these cases the current is called upon to supply the deficit. The point of first importance is that the energy of the secondary reactions forms an integral part of the energy of the circuit, and must be reckoned with just as strictly as the energy required for the primary decomposition of the electrolyte. The total chemical work of the current is represented by that required to transform the ingredients of the electrolyte into the compounds or substances which come into existence at the electrodes, whether of primary or of secondary origin.

Experimental determination of V^c and V^d.—An approximate determination of these important factors may be readily obtained during electrolysis. The former varies directly as the number of ampères passing, whereas the latter is independent of the current strength. If we therefore take two readings of the total voltage, V and V', with different strengths of current, A and A', the difference in voltage divided by the difference in ampères is R^c. We then have

$$V = V^c + V^d \text{ at } A \text{ ampères.}$$
$$V' = V'^c + V^d \text{ at } A' \quad \text{“}$$
$$\frac{V' - V}{A' - A} = R^c = \frac{V^c}{A} = \frac{V'^c}{A'}$$

Therefore $V^c = R^c A$ or $V'^c = R^c A'$

and $V^d = V - V^c$ or $V^d = V' - V'^c$.

The latter item, V^d, may also be observed experimentally by breaking the circuit and reading the back electromotive force. It falls usually very rapidly and so is difficult to obtain in this way. It is most satisfactorily observed in storage cells.

Calculation of V^c and V^d.—If we know the specific resistance of the electrolyte in ohms under the condition of the experiment, then R^c can be calculated from the size of the electrodes and their distance apart. Thus, let R be the specific resistance, then

$$R^c = \frac{R \times \text{distance apart in c.m.}}{\text{area in sq. c.m.}}$$

and, in any case

$$V^c = R^c \times A.$$

Subtracting V^c from the total voltage V, gives V^d.

In almost all electrolytes, R^c and consequently V^c decrease with rise of temperature and increased strength of solution.

The voltage lost in doing chemical work can be calculated when all the chemical changes taking place are known and their thermal value can be obtained in thermo-chemical tables. For a simple reaction, like the decomposition of melted caustic soda, NaOH, into melted Na and gaseous H at the cathode and O at the anode, it will suffice to know the heat of combination of melted Na, gaseous H and O to melted NaOH—all at say 216° C. If this is given in the tables, or can be calculated from the data given in the tables, then, calling this quantity Q, the heat energy furnished for one chemical equivalent of oxygen liberated is

$$\frac{Q}{2}$$

and the voltage absorbed in decomposition is

$$V^d = \frac{Q}{2 \times 23040}$$

In general, if Q is the heat of change of the final products to their state in the electrolyte, expressed per single chemical equivalent of oxygen liberated, then

$$V^d = \frac{Q_1}{23040}$$

It should be borne in mind that Q_1, and consequently V^d is determined only for the ingredients and products in certain definite physical states, at a given temperature, usually 15° C. and at normal atmospheric pressure.

For instance, if H_2 and O unite at normal temperature and pressure to liquid H_2O, evolving 69,000 calories, then

$$V^d = \frac{69{,}000}{2 \times 23{,}040} = 1{\cdot}50 \text{ volts.}$$

But H^2 and O at normal temperature, but at 10 atmospheres pressure would evolve 69,000 calories plus the work which

had been done in compressing them, which is 2,437 calories. Then

$$V^d = \frac{69,000 + 1,261}{2 \times 23,040} = 1{\cdot}53 \text{ volts.}$$

In other words, to decompose liquid water at 15° to hydrogen and oxygen at normal pressure requires $V^d = 1{\cdot}50$; but to do the same thing at 10 atmospheres pressure would require 1·53 volts. At 1000 atmospheres, the figure becomes 1·68 volts; while under an air pump, at 13 millimetres pressure, it sinks to 1·48 volts.

As to temperature, the above figure, 69,000, is good only at the temperature named, 15°, and for the gases at standard pressure uniting to *liquid* water at that temperature. The heat of combination at say 65° is different. It will be obtained by adding to 69,000 the heat necessary to warm the H_2 and O, at constant pressure, to 65°, and subtracting the heat given out by the H_2O falling from 65° to 15°. These amounts would be:

$$\left.\begin{array}{l}\text{To raise } H_2\ (65 - 15) \times 6{\cdot}82 = 341{\cdot}0 \\ \text{To raise O}\ \ (65 - 15) \times 3{\cdot}41 = 170{\cdot}5\end{array}\right\} 511{\cdot}4$$

$$\text{Evolved by } H_2O\ (65 - 15) \times 18{\cdot}3 = 915.$$

whence

$$\text{Heat of combination at } 65° = 69,000 + 511{\cdot}5 - 915 = 68,596{\cdot}5$$

and

$$V^d \text{ (at } 65°) = \frac{68,596{\cdot}5}{2 + 23040} = 1{\cdot}49 \text{ volts.}$$

In general we may then say, that the heat of formation of any product at any temperature is equal to its heat of formation at ordinary temperature, *plus* the heat necessary to raise its constituents from one temperature to the other (including in this any heat rendered latent by changes of state), and *minus* the heat necessary to raise the compound itself from one temperature to the other (including similarly any heat rendered latent by physical changes).

Having, then, the heat of combination at ordinary temperatures, the specific heats of the ingredients and of their

products, also their latent heats at critical points, we are then able to calculate the heat of formation at any temperature to which our thermal data extend, and thence to derive the voltage of decomposition at that temperature.

Another factor which may exert considerable influence on the voltage of decomposition of salts in aqueous solutions is the question of the dilution of the solution. This is a point often overlooked. The heat of solution of salts usually increases the greater the amount of water they are dissolved in; whence it follows that a greater voltage will be required for decomposition, V^d, for a salt in dilute solution (independent of any increase in V^c because of the poor conductivity of the weak solution.) If we should electrolyze zinc sulphate solution, endeavoring to precipitate all the zinc, the voltage of decomposition would increase slightly towards the end, as the last of the zinc was thrown out of the more dilute solution.

The next point to be considered, before classifying secondary reactions, is what the ions are in general.

For this information we rest almost altogether on the modern school of physical chemistry, Hittorf's researches being the pioneers. In the case of binary compounds, the basic ions appear at the cathode, the acid ions at the anode. In the case of ternary salts, the base appears at the cathode, the acid radical at the anode. Hittorf's researches were particularly illuminating, in showing the method of decomposition in salts of metallic acids, such as potassium chloroplatinate, sodium auro-cyanide.

SECONDARY REACTIONS.

I. The ions polymerize into more complex forms.
II. The ions decompose or dissociate into simpler forms.
III. The ions react upon the electrodes.
IV. The ions react upon the electrolyte.

I.

When the ions are simple, *i. e.*, composed of only one element, they are very probably atoms of that element. They can, therefore, either liberate the element simply as a

monatomic gas, or by polymerization as a more complex gas, liquid or solid—items depending mostly on the prevailing conditions of temperature and pressure, and possibly on the current density, *i. e.*, on the velocity with which the atoms are brought to the electrodes.

If fused mercurous chloride is electrolyzed above 350°, the mercury atoms will be liberated in the state of free atoms, as mercury vapor. Similar phenomena occur when melted sodium, potassium, zinc or cadmium compounds are electrolyzed at temperatures above the boiling points of the respective metals. Zinc iodide, at a high temperature, would give zinc vapor and iodine vapor both in the atomic state. It is only such rare cases that can be strictly regarded as instances of electrolysis without secondary reactions.

In almost all other cases of electrolysis the ions are not set free as atoms, but frequently polymerize to more complex forms, giving us the elements in their more usual molecular states. Molten sodium chloride at high temperatures furnishes monatomic sodium vapor and monatomic chlorine gas (Cl); at temperatures below 1200° monatomic sodium and diatomic chlorine gas (Cl_2). The voltage absorbed in decomposition would be less in the latter case than in the former, because heat is evolved when 2Cl passes into Cl_2 (quantity unknown). In the electrolysis of potassium iodide, if performed above 1500°, the iodine would be evolved as I, without polymerization, if below 1500°, as I_2. The change 2I to I_2 evolves 28,500 calories (Boltzmann). The voltage absorbed in decomposition would, therefore, be less in the latter case than in the former by the quantity

$$\frac{28{,}300}{2 \times 23{,}040} = 0{\cdot}62 \text{ volts.}$$

If potassium sulphide were electrolyzed above 1000°, the potassium would be evolved as monatomic vapor, while the sulphur atoms would unite or polymerize to S_2 vapor. Between 800° and 720° the potassium would escape as before, but the sulphur vapor would partly polymerize to S_6, and the voltage of decomposition be diminished. Between 710°

and 450° the potassium would polymerize to liquid metal, giving out thereby its latent heat of vaporization, and diminishing by just so much the heat absorbed in decomposition, compared with the higher temperatures. Between 500° and 450° the sulphur would evolve entirely as S_6. Below 450° the sulphur would polymerize to liquid sulphur, instead of gaseous S_6, and diminish the heat requirement by its latent heat of vaporization, a quantity not yet determined.

When water is electrolyzed under ordinary conditions, the H and O ions polymerize to H_2 and O_2 gas, and the voltage absorbed in decomposition, as calculated from the heat of union of H_2 and O_2 gas, is about 1·5 volts. At low temperatures, however, as much as 10 per cent. of the O atoms will polymerize to ozone molecules O_3. We do not know the heat evolved in 2H polymerizing to H_2 or 2O to O_2, or 3O to O_3, but we do know the value of the change from O_2 to O_3, which is

$$3O_2 = 2O_3 \text{ evolves } 72{,}000 \text{ calories.}$$

It thence follows that if the polymerization into ozone were complete, the voltage absorbed in decomposition would be less than that in the case of O_2 being evolved, by the quantity

$$\frac{72{,}000}{6 \times 23040} = 0{\cdot}52 \text{ volts.}$$

In general the deposition of most metals and evolution of most gases involves the unknown heat of polymerization from simple ionic atoms to the given molecular state, and we must content ourselves in the majority of cases with calculating the heats of formation for these bodies in the state in which they appear, which practically suffices, but scientifically is not so interesting as if we could analyze thermally all the different steps of the primary and secondary reactions.

II.

The dissociation of the ions into simpler forms is a phenomenon which occurs only with compound ions, *i. e.*, with radicals.

The general principle is that whenever the radical ion is not a chemical compound capable of existence at the prevailing temperature and pressure, then it must necessarily split up into chemical compounds which are capable or possible of existence.

Instances are numerous. The SO_4 radical from sulphates splits up into SO_3 and O, because there is no such chemical compound as SO_4.

$2NO_3$ from nitrates	splits into	N_2O_4 and O_2
$2P_2O_5$ " phosphates	" "	$2P_2O_5$ " $3O_2$
$PtCl_4$ " chloro-platinates	" "	$PtCl_4$ " Cl_2
$Au(CN)_2$ from auro-cyanides	" "	AuCN and CN
$2Al_2O_4$ " aluminates	" "	$2Al_2O_3$ " O_2
$2CrO_4$ " chromates	" "	$2CrO_3$ " O_2

Instances could be supplied at great length. The general tendency is for the radical to set free a minimum quantity of its acid ingredient, like O^2, Cl^2 or CN, and to leave the maximum quantity still in combination, forming the compound containing the largest possible quantity of acid ingredient; or, in some cases, the compound having the greatest heat of formation, so that the heat absorbed in the splitting up is a minimum.

We have no thermal data to apply to the successive steps in such secondary reactions, because the ion radicals are, by assumption, impossible chemical compounds.

It will be apropos here to make a general remark on the chemical nature of the liberated ions.

The cathions are the electro-positive ingredient of the electrolyte; they are chemically called the bases. They are always nearer to the metal or basic element, in composition, than is the electrolyte. If they react upon the electrodes or electrolyte their action is, in general, reducing; that is, they tend to bring elements out of combination towards the elemental state. Exceptionally, they act weakly in the opposite direction.

The anions are the electro-negative ingredients of the electrolyte; they are chemically acid elements or acid radicals. They are further removed from the electrolyte in *acid* character. If they react upon the electrodes or electrolyte

their action is, in general, the opposite of reducing, it is acidifying, tending to take compounds into higher states of combination. This influence is generally called in chemistry "oxidizing," because it so generally takes the form of higher oxidation; but the term is often misleading when applied to all these phenomena, and I much prefer to say "acidifying," or, to coin a new term, "*perducing*." This latter term is not at present an accepted one in chemistry, but its meaning is so clear—the reverse of *reducing*—that I strongly commend its adoption. It would be a term to cover what is now meant by oxidation in its general sense, whether oxygen be present or not.

III.

REACTIONS OF THE IONS UPON THE ELECTRODES.

A. At the anode.

B. At the cathode.

In either case the electrode may be a solid or a liquid, and the product may be

(*a*) A gas, soluble or not, in the electrolyte.

(*b*) A liquid, miscible or not with the electrolyte.

(*c*) A solid, soluble or not in the electrolyte.

A. (*a*) The reaction of the anion upon the anode, forming a gas, is a common secondary reaction, especially where carbon anodes are used in baths containing oxygen compounds. Such cases occur in the Hall process for producing aluminium, and in the fused-salt battery cells which use fused nitrates and a carbon pole. This latter reaction has been often proposed and investigated as a possible method of converting the energy of oxidation of carbon directly into electrical energy, and if a fused salt can be found which rapidly oxidizes at one temperature and is rapidly deoxidized by carbon at another, the problem may find some day a solution. The energy thus rendered available, would, however, be only that of oxidation to carbonic oxide.

Melted potassium chlorate splits up spontaneously at a red heat into chloride and oxygen, liberating thereby considerable heat. If poles of platinum and carbon are im-

mersed in the melted salt, the reaction will be explosive in its character, for the decomposing tendency of the salt alone is augmented by the heat of combination of oxygen with the carbon.

In the production of aluminium, by electrolyzing alumina in solution with carbon anodes, the oxygen burns the carbon to carbonic oxide gas.

$$\text{Primary } \overset{+}{Al_2}O_3 = 2\,Al + 3\,\overset{-}{O}.$$

Secondary, at cathode, x Al polymerizes to liquid aluminium.

" " anode, $3\,O + 3\,C = 3\,CO$.

This reaction at the anode evolves heat, and therefore lowers the voltage of decomposition.

We have $(CO) = 29{,}160$ calories at $15°$.

or, by calculation, $= 30{,}367$ " " $1000°$.

Whence, lowering of $V^d = \frac{30{,}367}{2 \times 23{,}040} = 0{\cdot}66$ volt.

A. (*b*) In refining any metal by electrolysis, the anion attacks the anode and re-forms the electrolyte. The heat of this reaction is the same as the heat absorbed in the primary electrolysis, and the secondary reaction thus exactly neutralizes the primary and V^d is suppressed, if the regeneration is perfect.

In precipitating copper from copper sulphate, using iron anodes, the reactions are

$$\text{Primary } \overset{+}{Cu}\overset{-}{SO_4} = Cu - SO_4$$

$$\text{Secondary, at anode, } -SO_4 + Fe = FeSO_4.$$

In each case, the salt is taken out of or goes into solution. We cannot analyze the different steps of this reaction, but we can take the total heats of formation of the two salts from their elements, and find their difference. For instance:

(Cu, S, O_4, aq.)	$= 198{,}400$ calories	$=$ primary.
(Fe, S, O_4, aq.)	$= 235{,}600$ "	$=$ secondary.
Excess evolved	$= 37{,}200$ "	

Therefore, voltage of decomposition

$$V^d = \frac{-37{,}200}{2 \times 23{,}040} = -0{\cdot}80 \text{ volt.}$$

In this case, therefore, the secondary reaction has furnished more energy than the primary required, and no voltage of decomposition is required, but the arrangement furnishes a voltage of 0·80 volt, and therefore acts as a battery with that electromotive force.

In precipitating zinc from zinc sulphate, using iron anodes, enclosed by a porous partition, energy is required as follows:

(Zn, S, O_4, aq.)	= 248,500 calories	= primary.
(Fe, S, O_4, aq.)	= 235,600 "	= secondary.
Deficit absorbed	= 12,900 "	

Therefore $$V^d = \frac{12{,}900}{2 \times 23{,}040} = 0{\cdot}28 \text{ volt.}$$

Where an insoluble compound is formed upon the anode, it either protects the anode from further oxidation, or may be a non-conductor and stop the current. If copper plates are used instead of carbon anodes in the aluminium process above referred to, cupric oxide is formed, which protects the metal underneath and yet conducts the current. (Cu, O) = 37,200. While the oxide is forming, the voltage of decomposition is reduced by about

$$\frac{37{,}200}{2 \times 23{,}040} = 0{\cdot}80 \text{ volt;}$$

but as soon as the coating is continuous this advantage is lost, and the whole voltage of decomposition for alumina alone is required.

These reactions are also largely employed for manufacturing electrolytically metallic compounds from the metals themselves. By electrolyzing a bath of sodium carbonate with a lead anode, lead carbonate is formed on the anode, which continually falls off by its loose adherence and exposes fresh surfaces of lead. This serves as the basis of several attempts to manufacture white lead electrolytically.

If sodium acetate solution is similarly electrolyzed, considerable lead carbonate mixed with hydrate is formed. Metallic sulphides are made by using the metals as anodes in hyposulphite solutions, the reaction probably being that the hyposulphite radical, S_2O_3, splits up into S and SO_3, the former uniting with the metal. (Process of Roepper and Richards.) The method serves for making artificial sulphides of mercury, cadmium and antimony.

A little different is the using of copper matte, Cu_2S, as anode in a bath of copper sulphate (Marchesi process). The copper is dissolved by the SO_4 radical, while its sulphur is liberated, and drops to the bottom of the bath. The voltage developed in the union of Cu with SO_4 exactly neutralizes or counterbalances the primary decomposition into Cu and SO_4, so that the net voltage of decomposition in such a case is simply that required to decompose Cu_2S into Cu_2 and S. But $(Cu_2, S) = 20{,}270$ calories, and therefore the net voltage of decomposition is 0·44 volts.

It will be remembered, by way of contrast, that in Salom's process a metallic sulphide is decomposed as *cathode*.

B (*a*) A gas may be formed by action upon the cathode whenever the latter contains an ingredient which can form a gaseous compound with the cathion. This is the case, for instance, when metallic sulphides are used as cathodes in solutions of acids, the hydrogen cathion thus forming with the sulphur gaseous hydrogen sulphide, and incidentally reducing the sulphide to metal. The gas will at first dissolve in the electrolyte, until the latter is saturated, and thereafter escape freely, as gas. Mr. Salom, of the Institute, has protected by patent this method of reducing ores, and is at present applying it at Niagara Falls to the production of spongy lead from lead sulphide ore.

When lead sulphide is used as a cathode in a bath of dilute sulphuric acid, the hydrogen set free at the cathode, reduces the sulphide to spongy lead, forming hydrogen sulphide. The voltage required for the primary decomposition is virtually that for decomposing water, or 1·50 volts. The secondary reaction includes the two quantities.

(Pb, S)	= 18,400	calories,	absorbed.
(H_2, S, aq.)	= 7,300	"	evolved at first.
(H_2, S)	= 2,700	"	" later.
Deficit absorbed	= 11,100	"	at first.
" "	= 15,700	"	later.

When the operation begins, the hydrogen sulphide first formed dissolves in the acid, the deficit is 11,100 calories, and the secondary reactions at the cathode, therefore, *increase* the voltage of decomposition, making it greater by

$$\text{increased } V^d = \frac{11,100}{2 \times 23,040} = 0{\cdot}24 \text{ volt.}$$

After the liquor is saturated with gas, the latter escapes freely and the

$$\text{increased } V^d = \frac{15,700}{2 \times 23,040} = 0{\cdot}34 \text{ volt.}$$

The voltage absorbed in decomposition in the bath is, therefore, 1·74 volts at starting and 1·84 volts when in regular operation.

B. (*b*) When a fused zinc salt is electrolyzed with a copper cathode, the deposited metal alloys with the copper and drops melted to the bottom of the bath. The voltage of decomposition absorbed in the bath is thereby diminished by the energy of union of the copper and zinc. The most fusible alloy forms first, $CuZn_2$, and since its heat of formation is 10,143 calories (J. J. Baker), its formation diminishes V^d, as follows:

$$\text{decrease in } V^d = \frac{10,143}{4 \times 23,040} = 0{\cdot}11 \text{ volt.}$$

In the Castner process of producing caustic soda, the electrolyte in one compartment is brine, the anode being unattackable and the cathode a bath of mercury. The sodium is absorbed by the mercury with great avidity.

Decomposition of NaCl — (Na, Cl, 13 H_2O) = 97,200 and $V^d = 4{\cdot}22$

Union of Na and Hg (Hg_x, Na) = 21·600 and $V^d = 0{\cdot}89$.

Whence it appears that the voltage for decomposition in this cell is reduced nearly one volt by this secondary reaction, becoming $4{\cdot}22 - 0{\cdot}89 = 3{\cdot}33$ volts. I have observed it myself as 3·3 volts.

In the other cell of the Castner apparatus, the sodium amalgam acts as anode, the electrolyte is water, and the caustic soda formed goes into solution. The reactions in this cell are as follows:

Primary decomposition of water	= 1·50 volts.
Decomposition of amalgam	= 0·89 volt.
Formation and solution of caustic	
$\frac{Na_2, O, aq. = 155,200}{2 \times 23,040}$	= 3·37 volts.

There is, therefore, absorbed in the primary reaction, 1·50 volts, absorbed in one secondary reaction 0·89 volt, or a total absorbed of 2·39 volts; while the other secondary reaction, the oxidation of sodium to caustic and its solution in water, generates 3·37 volts.

$$V^d = 1{\cdot}50 + 0{\cdot}89 - 3{\cdot}37 = -0{\cdot}89 \text{ volt.}$$

We see, therefore, that nearly one volt is *generated* in this half of the cell. The first half required 3·33 for decomposition. The voltage absorbed in decomposition for the whole apparatus is therefore $3{\cdot}33 - 0{\cdot}98 = 2{\cdot}35$ volts.

B. (*c*) Examples of union of the cathion with the cathode to form a solid are not common. One is the union of hydrogen ions with platinum or palladium, to form a solid hydride. The reaction is

$$(Pt_{30}, H_2) = 33{,}900 \text{ calories,}$$

and the corresponding diminution of voltage while this reaction lasts is

$$\frac{33{,}900}{2 \times 23{,}040} = 0{\cdot}74 \text{ volt,}$$

which quantity has often complicated the measurement of the voltage necessary for decomposition of water using platinum electrodes.

When sodium ions dissolve in quantity over 2 per cent. into a mercury cathode, the Hg_6Na formed is no longer soluble in the mercury, and separates out in the solid state. The thermal data are

$$(Hg_n, Na) \quad = 21{,}900 \text{ calories}$$
$$(Hg_6Na, Hg_x) = \ 2{,}900 \quad \text{“}$$

It appears, therefore, that when the liquid amalgam is formed, 2,900 calories less heat is given out than when the amalgam separates out as Hg_6Na. When this happens, therefore,

$$\frac{2{,}900}{23{,}040} = 0{\cdot}13 \text{ volt}$$

less voltage of decomposition is absorbed than when the Hg_6Na dissolves in the mercury; or, perhaps, it would be more accurate to say that the secondary reaction at the cathode assists more in the former case than in the latter, by 0·13 volt.

IV.

REACTION OF THE IONS UPON THE ELECTROLYTE.

A. At the anode: Oxidizing, acidifying or perducing actions.

(1) Formation of a gas.
(2) Formation of a solid insoluble in the electrolyte.
(3) Formation of a solid soluble in the electrolyte.

B. At the cathode: Reducing actions.

(1) Formation of a gas.
(2) Formation of a solid, insoluble in the electrolyte.
(3) Formation of a solid, soluble in the electrolyte.

A. (1) The anions have generally an acidifying or oxidizing action, which may in general be termed “perducing,” as opposed to the reducing action of the cathions. This influence is largely used in organic chemistry, for the purpose of oxidizing an organic compound. The chemical to be oxidized is dissolved in water, adding an acid or caustic alkali, as the case admits, then placed in a porous cell immersed in a larger jar in which is a dilute solution of acid or alkali. The oxygen set free at the anode in the atomic or nascent state acts very powerfully upon the organic compound, much more strongly than free oxygen gas would, and the current is continued until the desired degree of oxidation has been obtained. If the action is too strong or

too long continued, almost any organic compound present will be completely oxidized, literally burnt to carbonic acid gas or carbonic oxide gas and water. A good illustration of this action is when CS_2 is present in the electrolyte and oxygen is being liberated. The reaction is

$$CS_2 + 6O = CO_2 + 2SO_2$$

and a great amount of energy is thus liberated and added to the current, for CS_2 is an endothermic compound, whose decomposition *evolves* heat. We have the energy thus generated as follows:

Decomposition of CS_2 to C and S_2	=	14,100 calories.
Oxidation of C to CO_2	=	97,200 "
" " 2S to $2SO_2$	=	142,140 "
		253,740

This is for 6O; for 1O it will be 42,290, and the reduction in voltage of decomposition which it occasions by this secondary reaction is

$$Vd = \frac{42,190}{2 \times 23,046} = 0{\cdot}92 \text{ volt.}$$

In the above case a very interesting secondary reaction also occurs at the cathode, which will be considered later on.

A. (2) An example of this precipitation of an insoluble compound from solution by the action of the anion is the electrolysis of a solution of sodium hyposulphite containing dissolved silver chloride. Sulphur set free at the anode rapidly forms a black deposit of silver sulphide; which serves as one way of extracting the silver from such solutions.

If lead nitrate solution is electrolyzed with a platinum anode, a coating of lead peroxide, PbO_2, forms on the anode, caused by the oxidizing influence of the anion upon the lead nitrate solution.

A. (3) This principle of oxidizing or perducing the electrolyte at the anode is made use of largely in the chemical industries. The disinfecting of sewage is a case in point. Salt is generally present in the sewage in suffi-

cient amount (if not, it is added) and the liquid electrolyzed with aluminium or carbon electrodes. Chlorine gas is set free, in part, and hyposulphites are formed by the action of the liberated oxygen on the sodium chloride, resulting in a very satisfactory disinfecting.

The electrolysis of brine causes the formation of a considerable quantity of hyposulphite, and the liquid may then be used as a bleaching liquid. Such is the source of the "electrolytic bleach," so much used in paper mills and cotton factories.

Hypochlorites cannot exist in solution above 50°, so that, if the electrolysis of brine is conducted above that temperature, and the caustic soda formed at the cathode allowed to travel freely towards the anode, chlorate results. The action is probably that the chloride and caustic are simultaneously decomposed, giving OH and Cl ions at the anode. These unite to form HCl, liberating nascent oxygen, and the latter converts the NaCl present into $NaClO_3$. Practically all the potassium chlorate of commerce is manufactured in this way, by utilizing this secondary reaction.

The anion is often absorbed by the electrolyte, forming a higher compound. Thus, solution of cuprous chloride on being electrolyzed deposits copper at the cathode, but the chlorine set free converts the salt into cupric chloride at the anode. $CuCl + Cl = CuCl_2 = 18{,}755$ calories. The primary reaction (Cu, Cl) absorbs 32,875 calories (1·42 volts) but the secondary evolves, as above, 18,755 calories (0·82 volt) so that the net voltage of decomposition will be 0·6 volt.

This reaction may serve as the type of a whole host of similar actions which continue until part or all of the electrolyte is thus perduced. If, on the other hand, the metal separated out at the cathode is attacked by the "perduced" compound thus produced, then, when the latter mixes with the electrolyte and gets over to the cathode, there is "reduction" back again to its original state. Thus perduction of the electrolyte may be going on actively at the anode, and reduction of the same compound be going

on actively at the cathode, at the same time. The result will be a great falling off in the amount of cathion and anion finally remaining at the electrodes, the remaining amounts being far below what the current should separate out, according to Faraday's law. In fact, when some fused salts are electrolyzed, the perduction at the anode, the diffusion of the perduced salt in the electrolyte and the reduction at the cathode are so active and effective that no products of electrolysis can be found at all, under ordinary conditions, and the substance appears to conduct the current without decomposition. Such was the apparent metallic conductibility of fused lead iodide observed by Faraday, but finally explained as above by Beetz; and such is the reaction which occurs in the manufacture of metallic sodium by electrolyzing fused caustic soda. Above 325° re-combination on the above principles is so extremely active that 1,000 ampéres may be sent steadily through a small pot of melted caustic soda without any sodium being obtained; the bath lying quiet and appearing to conduct like a bath of metal; between 310° and 320° sodium is produced abundantly.

B. (*1*) When water is electrolyzed with carbon bi-sulphide present in it, the hydrogen ions, being nascent, act very strong on the CS_2 at the cathode, forming methane gas, CH_4, and hydrogen sulphide; the reaction being:

$$CS_2 + 8\,H = CH_4 + 2\,H_2S.$$

The heat equivalent of the secondary reaction is

Decomposition of the CS_2	14,400	calories.
Union of H_4 and C	21,500	"
" " H_4 and 2S	5,400	"
	41,300	"
For one atom H =	5,160	"

Whence, reduction of $V^{II} = \frac{5,160}{23,040} = 0{\cdot}22$ volt.

If we consider this reaction in connection with the secondary oxidation reaction at the anode, the voltage of decomposition is lowered by the presence of the carbon

bi-sulphide 0·22 volt at the cathode, and 0·92 volt at the anode, a total of 1·14 volts. This great reduction in voltage and the liberation of methane at the cathode may, together, account for the beneficial results obtained in gold plating by adding carbon bi-sulphide to the bath.

The remaining examples of secondary reactions at the cathode include many very important chemical processes. The cathion may act upon the solvent or upon the salt being electrolyzed; it may produce compounds soluble or insoluble in the bath. The general action being reducing, lower salts are often formed.

If, for instance, I electrolyze cuprous chloride, CuCl, the chlorine evolved at the anode may combine with the bath to form $CuCl_2$, and so rapidly that almost no chlorine visibly escapes; but the copper cathion cannot act upon CuCl in any way, because this is the compound of copper with the least amount of chlorine, and therefore the normal amount of copper will separate out. On the other hand, if I electrolyze a solution of cupric chloride, $CuCl_2$, the conditions are the reverse; the normal amount of chlorine will be set free at the anode, because $CuCl_2$ cannot be perduced to any higher chlorine compound; but at the cathode the copper will largely, if not entirely, reduce the $CuCl_2$ down to CuCl, and thus almost none remain on the cathode.

When the cathion is an easily oxidizable metal, it may react upon the water present in the electrolyte, set free hydrogen and form an oxide, which passes often into an hydrated oxide if it has power to combine with water. In the case of the metals of the alkalies, they decompose water rapidly and their hydrates formed are soluble in water. We thus obtain solutions of their hydrates, or caustic alkalies. If the metal oxidizes rapidly to an insoluble hydrate, like magnesium or aluminium, the cathode soon becomes covered with the white layer of oxide and the current is sometimes thereby interrupted.

Other reactions are the reduction of organic compounds by placing in their solutions some salt of sodium, and then electrolyzing them in a porous cell, with the cathode immersed in them. The reducing action is strong and is util-

ized for the same purpose as ordinary reduction by sodium or by zinc dust, or other reducing agents.

B. (*2*) A good example of this action is the deposition of gold at the cathode when electrolyzing a solution containing potassium auro-cyanide, $K_2Au(CN)_2$. It has been proven by Hittorf that this salt decomposes as follows:

$$K_2Au(CN)_2 = \overset{+}{K} - \overset{-}{Au(CN)_2}$$

The anion splits into CN gas, which is evolved, and Au CN which goes again into solution. At the cathode the K ions react on the auro-cyanide in solution, depositing therefrom Au, as follows:

$$K + K\,Au(CN)_2 = Au + 2\,KCN$$

The precipitation of the gold is thus purely a secondary reaction. The thermal data for calculations are lacking.

Another illustration is the electrolysis of solutions of aluminium salts, such as $AlCl_3$. The aluminium ions decompose the water, forming aluminium hydrate. The reactions are:

Primary	$2AlCl_3 = \overset{+}{2Al} - \overset{-}{6Cl}$
Secondary, at cathode . . .	$2Al + 6H_2O = Al_2O_3.3H_2O + 3H_2$

The thermal reactions are:

Absorbed in primary	2 (Al, Cl_3, aq) = 475,560
Decomposition of water	3 (H_2, O) = 207,000
Formation of aluminium hydrate	(Al_2, O_6, H_6) = 388,800
Net heat evolved in secondary action	181,800

The voltages of decomposition are therefore:

Primary V^d absorbed $= \dfrac{475,560}{6 \times 23,040} = 3{\cdot}44$ volts

Secondary V^d developed $= \dfrac{181,800}{6 \times 23,040} = 1{\cdot}32$ "

Net V^d in the electrolysis . . . . . $= 2{\cdot}12$ "

This reaction is utilized in electrolyzing impure water, after adding an aluminium salt, whereby the water is oxygenated and purified at the anode, and the aluminium hydrate precipitated at the cathode carries down impurities mechanically.

B. (*3*) The formation of alkaline hydrates is the best example of this kind of secondary reaction. In electrolyzing sodium chloride solution, using unattackable electrodes, the primary decomposition is into sodium and chlorine; the secondary reaction is the decomposition of water by the sodium. We have, therefore,

Primary decomposition (Na, Cl, aq.) . .	= 96,510 cal. = 4·19 volts.
Decomposition of water =	69,000
Formation of caustic .	= 111,810
Net heat of secondary reaction	= 42,810 cal. = 1·86 volts.
Net heat of primary and secondary . . .	= 53,700 cal. = 2·33 volts.

This reaction is the basis of several processes for producing caustic soda from brine, using a porous partition to keep the caustic produced to itself.

In conclusion, one may well say that to understand secondary reactions properly, is to have an insight into the most subtle problems of electrolysis, and puts one in position to understand the why and wherefore of all electrolytic processes. This knowledge cannot be gained except by having a thorough working knowledge of chemistry, a complete acquaintance with electrical experimenting, practice and theory, and an ability to see, to think and to search for oneself. The electro-chemical and electro-metallurgical industries are at present in need of men with the above equipment, and the progressive universities and technical schools of our land are giving increasing attention to supplying that need.

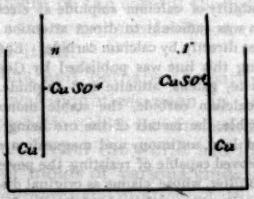
Department of Metallurgy,
Lehigh University, March 4, 1901.

DISCUSSION.

Mr. Jesse Pawling, Jr., asked whether it is not true that when a salt is in solution it is broken up into ions, whether a current is passing or not? This was answered by Dr. Richards in the affirmative and he stated that when no current was passing, the molecules were arranged in no particular order, and that a current had the effect of directing them so that one set of ions, the positive, go to

the cathode, and the other, the negative, go to the anode. At the meeting of March 21st, DR. RICHARDS, in answer to some question, stated that the metals were liberated at the kathode in a metallic form, while they were liberated at the anode, if at all, in combination, unless there is a combination of a metal with an element which has both metallic and non-metallic properties, in which case the more metallic element goes to the cathode and the less metallic to the anode. MR. PAWLING asked if this were always true and Dr. Richards answered in the affirmative, illustrating the latter part of the statement by the compounds of tellurium. In nickel telluride, the nickel goes to the cathode, while the tellurium goes to the anode. In tellurium sulphate, the tellurium goes to the cathode, while the sulph ion goes to anode as usual.

MR. REED remarked that but a small current would be



passed through a solution in which there was no mechanical agitation and emphasized the fact that mechanical agitation was necessary.

MR. PAWLING made the accompanying sketch on the blackboard, and asked whether if a current be allowed to pass if a Cu ion would not be dissolved from the anode and be combined with the SO_4 ion of 1, while Cu ion of 1 would not be combined with the SO_4 ion of 2, and so on to *n*, which in turn would give its Cu ion to the cathode. This MR. REED confirmed and also stated that mechanical agitation was necessary, because the solution in the neighborhood of the cathode would soon become dilute and but little current would pass, due to chemical action alone.

MR. CARL HERING stated that in his investigation of the action of a current in depositing lead in combination on either anode or cathode depending upon the oxide of lead forming one or the other, he used a porous partition to see upon which side the lead (or lead compound) would be deposited and hence tell which way the constituents went. He stated that the partition clogged up. MR. PAWLING asked from which side the clogging took place. MR. HERING stated that the partition simply clogged up without showing any direction of deposit.

SULPHIDE ORES

cannot, as a rule, be reduced directly by carbon, but must undergo a preliminary roasting operation to remove the sulphur, the last traces of which are eliminated with extreme difficulty, says the *Electrical World and Engineer*. Accordingly, when Mourlot directed attention some three years ago to the remarkable stability of calcium sulphide at electric furnace temperatures, the observation was sufficient to direct attention to the possibility of reducing sulphide ores directly by calcium carbide. Early in 1900 an account of investigations along this line was published by Geelmuyden, who found that pyrite, tetrahedrite, galena, stibnite and sulphide of magnesium were readily reduced by calcium carbide, the stable monosulphide of calcium remaining in the crucible, the metals of the ore being liberated and, in the cases of compounds of lead, antimony and magnesium, volatilized. Aluminium sulphide alone proved capable of resisting the powerful reducing agent.

M. Louis Michel Bullier, whose claims as original discoverer of crystalline calcium carbide have been recently upheld by the French courts, now describes an interesting extension of the foregoing principle, whereby the metals are recovered directly from mixed sulphide ores and an efficiency of nearly 90 per cent. is obtained. If copper sulphide be fused in presence of a suitable flux for which a blast furnace slag, melting, according to the patent, at about 1,500° C. is found available, and calcium carbide added in theoretical proportions, the reduction occurs readily, the calcium sulphide dissolving in the slag and the copper being recovered as an ingot free from sulphur. If copper pyrites be subjected to the same treatment it is found that the ingot obtained is composed by two sharply separated layers, of which the lower is copper and the upper iron saturated with carbon. For ores containing zinc or other metal volatile at the temperature used, a closed retort may be employed and the vapors condensed in the usual manner. The reduction of copper pyrites by this method requires an amount of 80 per cent. carbide somewhat exceeding the weight of the ore; for copper sulphide the carbide and ore are used in the ratio 1 : 2.

Mechanical and Engineering Section.

Stated Meeting, held February 14, 1901.

THE JIG HABIT IN AMERICA.

BY OBERLIN SMITH.

ABSTRACT.

The subject we have in view deals not only with those tools known as jigs, but with analogous tools of various kinds which are used for cheaply reproducing certain predetermined shapes and locations.

The grand principle of the reproduction and duplication of artistic and utilitarian forms, the originals of which were the direct embodiment of the careful thought of the artist and the engineer, is in some manifestation or other, almost as old as the world itself.

The most obvious, and perhaps the earliest, application of this principle was doubtless seen in the molding of plastic materials which could be afterwards hardened, as clay, soft metal, etc. After the world had long been accustomed to the use of molds of various kinds, the products of which could be numerously duplicated, the most notable application of the general principle which appeared was undoubtedly shown in the art of printing—from permanent engravings and afterwards from movable types. Other instances of this principle may be seen in the making of chromos and other lithographs; in the use of stencils; in the coining and stamping of metals by the use of presses and dies; and in casting metals and other substances.

A further application, differing somewhat in principle, may be seen in the use of turret-lathes and similar devices, where cutting tools are arranged for an exact repetition of their proper location, to avoid hand adjustment for each piece of work to be operated upon. A somewhat similar principle may be seen in profiling and pattern-turning machines, so called, where the movement of cutting tools

is governed by their being made to follow a master model of the work to be produced. Another instance of the same principle is seen in Jacquard looms and other weaving machines where a prearranged design, fresh from the soul of the artist, is duplicated numberless times by the use of automatic machinery, attended by cheap labor.

Still another application of the principle, and one in which we are more interested this evening, is the use of gauges, templets, cradles and jigs, these being chiefly used in the paring and cutting, to exact finished shapes, of pieces of metal which have been more roughly formed by the processes of casting or forging.

The functions of a cradle and jig are sometimes combined with those of the drilling- or boring-machines in which they are used, in the shape of a special machine which is fitted for one purpose only and which is adapted for locating the work to be operated upon, as well as the tools, in absolute predetermined positions. A good illustration of such a machine is seen in the special multiple-spindle driller which is used for boring, counter-boring, facing, reaming and tapping all the holes in a mowing machine frame, at one operation, with the assistance of cheap labor. This machine works with sufficient accuracy for the purpose, and in $\frac{1}{10}$ or $\frac{1}{30}$ of the time that would be required by ordinary methods with good machine-tools and high-priced workmen.

Speaking first of gauges, which are well enough known to make a detailed description unnecessary here, even were there time to treat of the numerous forms in which this tool appears: their general function is to inspect and verify standardized measurements. In accurate work, limit-gauges (so called) are frequently used, one representing the maximum and the other the mimimum sizes, which are allowable, the work varying between these limits at different times and to different degrees, such variations obviously representing human fallibility when attempting absolute accuracy. The purpose of a gauge is usually not so much to locate the position of various finished surfaces in a piece of work, as to inspect them and report upon them after they are so located.

Going a step farther, we have tools known as templets, which are usually flat pieces of metal (often thin sheet-metal) which are laid upon various surfaces of the work, being located by the eye or by proper flanges, pins, etc., certain edges of the templet, interior or exterior, being used to rest a scriber, or other pointed marking tool against, while marking the position of exterior edges, or of holes or grooves to be cut below its general upper surface. Such a tool will, of course, reproduce marked lines with considerable accuracy, but the drilling or cutting to these lines afterwards is subject to various errors, depending somewhat upon chance and somewhat upon the skill of the operator. If we make a templet thicker than usual and fasten it securely to the work, using the locating edges for the actual guides for cutting tools, we have the simplest form of flat jig, somewhat as shown by this pasteboard model which I have in my hand. When the exterior edges of such a jig are used to locate finished edges in the work, the tool is often known as a filing or milling jig, as the case may be. By far the most usual function of a jig, however, is to locate cylindrical holes of various sizes and kinds as made by drills and other boring tools. The simplest form of flat-jig is usually a plate of steel with certain holes accurately drilled through it at right angles to its upper and lower surfaces. If these same holes are to be drilled in a rectangular block of metal, for instance, of the shape of an ordinary brick, as represented by the wooden model I hold in my hand, then it is obvious that if the same is laid upon the horizontal table of a vertical drilling machine, with a jig clamped upon the top of it, the external edges being made to coincide by the sight or feeling of the operator, the holes in the jig may be exactly reproduced, as regards location, in the piece of work—providing the drilling tools fit the holes in the jig without shaking. Furthermore, these drilled holes may be made of any desired depth by proper adjustable stops to limit the downward motion of the drill-spindle.

In practice, such a jig as is above mentioned is often made somewhat in the form of a box-lid with downward projecting flanges or pins to slip over the work, so that it

need not be located by hand. Sometimes, clamps, screws or other fasteners are used upon one or more sides of such a jig to pull it over in one direction, so that it may be located by certain fixed edges of the work which are the most suitable. Should the work vary somewhat in size, as is the case with rough castings or forgings, it is sometimes desirable that the clamping should be central and should be done from all directions, somewhat after the manner of a universal chuck. A jig of this sort may in general be called a lid-jig and is roughly represented by the pasteboard box-lid here shown.

Carrying development still further, we have the box-jig which stands upon its own bottom, so to speak, and into which the work is dropped and clamped in various directions, sometimes by the action of closing the lid—which may be hinged or otherwise secured thereto. If it is desirable to drill holes variously located and parallel to each other, in one direction only, through the piece of work in question, the jig, of course, always stands upon its bottom. It may, however, be required that other holes in other directions shall also be drilled. Thus, it is often the case that a jig, if of an approximately cubical shape outside, is turned over upon several or all of its six sides, the holes being drilled, of various depths, from any of the six directions, represented by lines normal to the various sides of a cube. Should still other directions be required, the outside of the jig can, of course, be made with various working "bottoms," upon which it can be temporarily laid. These can be at any desired angle with each other, and each is, obviously, placed opposite to the surface where the holes are provided for the drill to enter.

One of the most common illustrations of the use of jigs of this sort is found in the drilling of sewing-machine frames, where the work usually consists of an iron casting of very irregular shape. Being dropped into its jig, it is located by certain surfaces which are most favorable for producing uniformity; in some cases some or all of these surfaces being previously finished by milling, or otherwise. This jig is then slid along upon the table of a gang drilling

machine, each spindle of which carries the proper tools for drilling, boring, reaming or tapping certain holes. The downward stroke of each tool is governed by a proper stop, and thus, by cheap labor, any number of accurate holes may be located and drilled in rapid succession by a proper manipulation of the jig, it resting on any desired bottom and being pushed along from one drill-spindle to another. In such case the work is, of course, not disturbed in its position in the jig, during the complete operation in question.

In some cases a simpler form of the above-named jig can be used, the general shape of which is a flat plate with various legs projecting downward. Its general form may appropriately give the name of stool-jig to a tool of this kind. The work is placed between the legs and clamped up against the plate, not having a proper bottom of its own on which to rest, as is the case with the lid-jig.

Another modification of the box-jig may be known as a skeleton-jig, which, instead of having complete sides enclosing the work, is made in the form of a light skeleton frame. This tool is often necessary in heavier work than that above described where it is desirable to save weight as much as possible in order that the operator may be able to easily handle, unaided, the combined jig and work.

It is obviously impracticable to treat heavy castings, such as the beds of lathes or the frames of large presses, in the jigs above mentioned. In such case it is well to do the turning, milling and planing by ordinary methods, locating the finished surfaces by various gauges and templets, after which local jigs, as they may be called, are applied for accurately locating holes by some of the finished surfaces already produced. These jigs are made to suit one or more holes, as the case may be. Being small enough to handle conveniently, they may be placed in succession on various parts of the large piece of work in question.

In making large jigs a very important point is to make them light for easy handling, but yet to get the utmost stiffness possible by very careful designing, that they may not warp, bend or twist when fastened to the work, thus throwing the holes, etc., out of place. It is usually best to

use cast iron for the frames of jigs, because the working parts will maintain their position unless strain enough is brought upon them to actually crack the casting. Jigs, on the other hand, made of forgings, steel castings or brass castings are apt to bend without its being known, thus destroying their accuracy and perhaps spoiling large quantities of work before the error is discovered.

In jigs for accurate work, and where large quantities of pieces are to be made, all holes should be bushed with hardened and ground steel bushings, made to standard external diameters that they may be easily replaced when their interior surfaces are worn by drills or other boring tools which revolve therein. In jigs for making work in large quantities these bushings are usually securely fastened in place, but so that they can be knocked out when too much worn. In other cases, where the jig is used for larger work and has to perform upon but few pieces at a time, interchangeable bushings are often employed, a full set of them being kept in the tool room which can be used at random in various jigs.

Cheap jigs for a small quantity of work are sometimes made by drilling the working holes through the body of the cast iron of which they are made. These, of course, are durable only to a limited degree. In some cases, instead of bushing each hole, a hardened steel plate, with the proper working holes drilled through it, is fastened to the frame work of the jig proper. One difficulty in this system, however, consists in the fact that the warping of the steel in hardening is apt to somewhat displace the holes in their relation to each other.

The title of this lecture implies that there is a state of mind and a state of practice known as a "jig habit."

The tendency to use not only jigs themselves, but analogous tools embodying the same grand general principle for the accurate and rapid development of interchangeable parts of machines and other structures may be termed a habit of mind. Why this mental condition is prevalent in certain places and with certain people more than at other places and with other people, is a question for the psychol-

ogist. That it does exist to a greater extent in North America than in other countries in the world, and that it is found more especially in that class of Americans (no matter where they are born) whom we may term "Yankees," is, I think, an indisputable fact. These people are of a class who are born to be mechanics, and who have been brought up in an atmosphere permeated with intense practical energy.

The American who possesses this habit (usually both born and acquired) seems to have been developed during the last hundred years or so by reason of coming, in the first place, from good English and other European stock in whom common sense is a chief characteristic. The evolution of the jig habit seems to have come from these men being cast upon their own resources in a new country, where novel and original methods were often forced upon them, and where much freedom of thought and action enabled them to study for themselves methods which would allow them to carry out their mechanical ideas upon the most economical basis—not only for the love of the money to be procured thereby, but from an innate love of mechanical things put into their simplest forms.

SLAG-WOOL FOR BUILDING WORK.

The English journals have lately been calling the attention of their readers to the considerable extent to which the so-called mineral-wool, or slag-wool, is used as a non-conducting filling in floor and partition spaces in building construction in the United States. They refer to the fact that the material is excellently adapted for this purpose on account of its absolute cleanliness, that no vermin of any sort will live in it, that it is an admirable preventive of the spread of fire through hollow walls, floors and partitions, while its heat insulating quality for the purpose of keeping walls and floors at uniform temperature is no less valuable. One of the prime advantages of the material, in fact, is the last named property of warmth and in the saving of fuel resulting from its use in filling the space between the studding. One of the leading iron trade papers in England speaks of the product as an ideal material for such use in buildings, and attributes the neglect of it by English architects to the circumstance that it was first used largely for steam-pipe coverings, a use for which it is least adapted, because of its disposition to pack in certain parts of the pipes on account of the constant jarring to which most steam-pipes are subjected. Also it is intimated that considerable misapprehension exists as to its cost. Neither of these objections apply in the present case, as it is very well adapted for building uses and is comparatively inexpensive. W.

SOLDERS FOR ALUMINUM.

The one great drawback to the application of aluminum for a large number of uses in the arts for which its lightness, color, resistance to oxidation and the ease with which it can be rolled, drawn into wire, pressed and spun up into various shapes, etc., is the difficulty of soldering joints. While some approximations have been made to a durable solder, among which that of Richards' should be named, it is nevertheless true that an entirely satisfactory solution of the problem has yet to be found.

The difficulties encountered are threefold: (1) The high heat conductivity of aluminum, which abstracts heat rapidly from the joint and (2) galvanic action between the aluminum and the metals of the solder by which the aluminum, the more electro-positive metal, is corroded and the joint destroyed.

It is comparatively easy to make an apparently perfect soldered joint of aluminum with various mixtures of zinc and tin, for the reason that when freshly made, the adherence is all that could be desired. The effects of the galvanic corrosion may make themselves apparent after the work has been exposed to atmospheric influences for some months. The rapid heat conductivity of the metal can be practically obviated by applying artificial heat to the joint while the solder is being applied. It has been proposed to use aluminum in considerable proportions in the solder to avoid the effects of galvanic action, but while this artifice might accomplish the desired result, the joints cannot be made with the soldering iron, because of the high heat required to melt the alloy. A perfect solder for aluminum is still to be found. W.

CONCERNING CALCIUM CARBIDE.

In a recent article on the analysis and purification of acetylene, Rossel and Landriset quote figures which show that the proportion of hydrogen by volume in commercial acetylene usually ranges from 0·2 to 0·3 per cent., and does not exceed the latter limit even when the carbide is made in the presence of an excess of lime, says the London *Electrical Review*. Using an alternating current in the furnace, part of the lime excess volatilizes and part melts without decomposition, yielding a carbide of specially fine crystalline appearance; only the small residue is dissociated to metallic calcium, and, according to the present authors, only that part of the residue which happens to be in the middle of the finished lumps of carbide remains as metal, and generates hydrogen when it comes in contact with water. Hydrogen in acetylene is objectionable since, burning as it does with a non-luminous flame, it reduces the illuminating power of the crude gas. It is known that a considerable quantity of hydrogen may exist in acetylene when the gas has been generated in a faulty apparatus which encourages overheating, and the quantity may easily reach a figure that seriously affects the reading of the photometer. This hydrogen is due to various decompositions occurring in the process of evolution, and it can be totally avoided by proper construction of the generating plant. The hydrogen arising from the metallic calcium of the carbide is naturally unavoidable; but Rossel and Landriset clearly show that its amount is too small to be in the least degree sensible to the consumer. Indeed, it is difficult to understand how any appreciable amount of metallic calcium can appear in a material made in an alternating furnace, where true electrolysis is theoretically excluded.

Section of Photography and Microscopy.

Stated Meeting, held Thursday, February 7, 1901.

THE WAGER EXPOSURE SCALE FOR CORRECTLY TIMING PHOTOGRAPHIC NEGATIVES.

By E. WAGER-SMITH.

It is probable that you will all agree with me that, for the beginner at least, the correct exposure of his negatives is the *sine qua non* of his success, and even when he understands how to correct the exposure during development, and how to intensify and reduce his negatives after development is completed, he will save himself a great deal of useless drudgery, and will have very much better success if, at the outstart, he correctly exposes his plates.

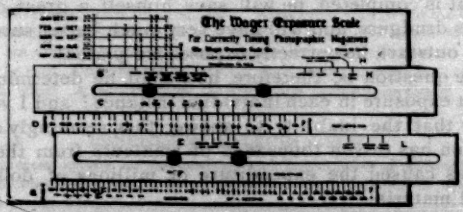
The question is, therefore, how shall he determine this correct exposure in each individual instance? and I venture to say that the inability to answer this seemingly simple question has driven thousands of amateurs from the field, and has caused the expenditure of millions of dollars in ruined material.

Some claim that through long years of experience they have learned to "feel" what the correct exposure should be, but it has been pretty clearly shown that this "feeling" is nothing more than knowledge, and does not extend much further than cap exposure, with regular known stops and plates.

The next time any one tells you that he can "feel" the correct exposure in every case, ask him how long he would expose a given subject, using, say an f/26 stop, and a plate 7½ times as slow as the fastest made, and you will find that unless his mental arithmetic is of a high order, he will need a paper and pencil to figure it out.

I think this shows quite conclusively that he merely "feels" what he knows, and no more, and as his knowledge is only partial, his "feeling" will be only partial, and therefore inadequate to the demands which will be made upon it.

Others will tell you that the only way to be sure you are going to give your subject the correct exposure is to first refer to some similar exposure you have made, and gain knowledge from that. Aside from the obvious fact that if the beginner were to follow this advice literally, he would never reach the point where he could expose a plate, for he would never have a record to which he could refer. If you consider the size of the note book we would require for this purpose, the months and years which would elapse before it was filled, or even half filled, and lastly, the time it would take to find the record of an exposure similar to the one you were about to make, it seems to me that the scheme would hardly recommend itself to the thoughtful amateur.



You might think that the professional had solved the question of exposures, and he has—up to a certain point.

He goes just about as far as the man who feels.

Further, the range of a professional's work cannot, as a rule, compare with that of an amateur. The latter may be compelled to make two exposures within five minutes of each other, the first one requiring $\frac{1}{100}$ of a second, and the other ten seconds, or 1,000 times as long. It may even become necessary for him to make two exposures on the same day, one of which will be 500,000 times as long as the other.

Now, let us consider for a moment the factors which govern the length of an outdoor exposure.

We have, in the first place, the month of the year, the hour of the day and the condition of the weather—these

three give us the actinic value of the light. Then we have the subject, the size of the diaphragm and the speed of the plate.

There are also two other factors, which have as much bearing on the subject as those mentioned. The first may be expressed by one of the best maxims ever laid down for the guidance of beginners. It reads: "The temperature of the developer is of just as much importance as the length of the exposure." The other factor lies in the fact that the shutters now on the market do not, as a rule, give the lengths of exposure for which they are marked, the one hundredth of a second ($\frac{1}{100}$) speed, will usually be found to be between ($\frac{1}{50}$) one fiftieth and ($\frac{1}{25}$) one twenty-fifth. The best plan, of course, is to get a speed tester and ascertain just what length of exposure the various markings give.

To return to our six main factors—the strength of the sun at different seasons of the year and at different hours of the day may be readily calculated. Rules which have proved to be correct have been laid down regarding the different amounts of time necessary under different conditions of the atmosphere.

Laws governing the time necessary for varying subjects have also been formulated.

The stop or diaphragm is a simple matter of multiplication and division, and the speeds of different plates is merely a matter of testing.

These different factors were tabulated in book form some time ago, and while serving their purpose to a certain extent, did not allow one to ascertain the correct exposure as swiftly as desirable, did not allow one to check the result, without going through the whole operation a second time and, as the different factors had to be carried in the mind from one page to another, magnified the possibility of an error being made.

Exposure indicators, depending on sensitized paper for their results, have also been used to some extent, but on account of the treacherous nature of this material (for this purpose) have never been favorites with the majority.

It occurred to me that if an exposure indicator could be

devised which would eliminate the undesirable features of the two styles mentioned above, it would be a great help to every amateur in the country. I decided that the then embryotic indicator *must* embody the following good points: It must be accurate, it must be simple. It must be so arranged that the operator need do no mental arithmetic whatever. It must be so arranged that the result could be checked simultaneously, and its speed of working must be phenomenal. After a long time, I brought it to the desired point, and I think you will find that it has every one of the good qualities I determined it should have at the outstart.

You will notice that the device is composed of three pieces, two of which slide upon the third, and as the best way to show you the working of the invention will be to select a certain set of factors, and see what exposure their combination gives, we will suppose that you wish to take a photograph of a snow scene at 9 A.M. in January.

Selecting the horizontal line for January (at the top of the scale) we follow it with the eye to the point marked 9 A.M. We then move the upper slide until the line for "snow" is immediately below this point, and without further manipulation of the device, find that the exposure with a No. 16 stop is ($\frac{1}{25}$th) one twenty-fifth of a second (this being found on the central scale "D," immediately below the "stop" scale "C").

If the sun is intense and fastest plates are being used, we proceed at once to take our picture. But we will suppose that the sun merely casts a faint shadow, and that we are using a Cramer slow iso plate. We would then move the lower slide so that the word "hazy" would come right below $\frac{1}{25}$th second (already found) and upon looking below "7" in the "F" scale would see 1 second in the "G" scale. This would be the proper exposure under the six different conditions named. I should say here, that the different standard plates on the market are arranged in numbered groups on the reverse of the scale according to their speed, and that "Cramer Slow Iso" will be found in group No. 7.

I have also added the scales "H," "K" and "L," which, in conjunction with the scales "C" and "F," give the correct exposure for interiors under ordinary conditions.

I am glad to say that the words "patent applied for" are no longer correct, as my application was granted just a few days ago.

If anyone has any questions to ask, I shall be happy in answering them.

DISCUSSION.

MR. ALTENEDER:—"Will you explain how you obtained your results?"

MR. WAGER-SMITH:—"I took for my starting point, the fact that in June, at mid-day, with an intense sun overhead, one twenty-fifth ($\frac{1}{25}$) of a second will be required, when using a No. 16 stop, to correctly expose an average landscape. The sun's strength on any day may be represented by a curved line, and if ordinates be erected at the proper points, and their length compared with the ordinate for June 21st at 12 M, the proportional sun strength of the hour and day under consideration will become apparent.

Different subjects require more or less time than an average landscape, and I have proved that the constants which I employ are correct; the same may be said of the different conditions of the atmosphere, while, as I remarked before, the stop is a case of multiplication or division, and the plate is a matter of testing.

I believe this answers your question in a general way.

NOTES AND COMMENTS.

FILTH IN SAUSAGE SKIN.

Dr. Shilling is credited with the discovery of a new mystery in the composition of that already sufficiently mysterious article of diet—the sausage. Says the London *Lancet*: "He had often remarked molds lodged in the inequalities of the inner surface of the skin. He examined pieces of dried gut such as are found in the market, and was surprised to find adhering to them a considerable amount of *débris* of straw and fragments of grain. He argued that if such remains were fairly abundant after drying, they must be still more so in the fresh guts used by pork-butchers. He had some difficulty in procuring samples, as only enough is prepared for the needs of the makers, and they are not willingly sold. After repeated examinations, he satisfied himself that these intestines of oxen or pig contained an amount of excremental matter which may be estimated at from 2 to 2½ grams per meter [10 to 12 grains to the foot] of small gut, and 5 per metre of large. If the skin of sausages is carefully removed, only a small part of this filth is swallowed; but, if they are eaten with the skin, a considerable quantity must be swallowed. Dr.

Shilling estimates that a German workman consuming 10 to 13 centimeters [4 to 6 inches] of sausage daily swallows 4 to 5 grams [62 to 77 grains] of excrement in the week, or 20 grams per month. One need only, he says, see the butcher prepare the guts by washing in a little dirty water to know in what state they must be in regard to cleanliness. He admits that it is not easy to clean the intestines thoroughly, and he is not clear as to the pathological effects that may be caused by eating the matters referred to. There can be no doubt, however, that such substances answer to the definition of dirt as 'matter in the wrong place,' and, to say the least, they can hardly be regarded as wholesome articles of food. They are certainly not appetizing. Hog's dung taken in water and wine had a great reputation in the Middle Ages as a remedy for blood-spitting and pain in the side. But the return of the *Saturnia regna* of organotherapy which appears to be in prospect has not yet led us to this particular medication. And, whatever may be its therapeutic virtues, most people would probably prefer not to have it administered in their morning sausage."

THE NATIONAL BUREAU OF STANDARDS.

The *Popular Science Monthly* says: "The bill establishing a National Bureau of Standards, which was passed by Congress in the closing hours of the session, is a measure of unusual importance for science and for industry. Such an institution has long been urgently needed. Germany expends $116,000 annually on its corresponding institutions, and it is not difficult to trace an immediate connection between its Reichsanstalt and the supremacy of German scientific instruments and the increasing manufactures and export trade of the nation. Great Britain has recently been persuaded by the British Association and the Royal Society to extend its work, and is now erecting a new physical laboratory, while it provides $62,000 annually for the cost of its different institutions engaged in standardizing and experimental tests. In the United States the sum of only $10,400 has hitherto been set aside for the Bureau of Standard Weights and Measures, which has now been converted into a National Bureau of Standards. For the bureau a building is to be erected which may cost $250,000, though only $100,000 is at present appropriated; $25,000 is allowed for land and $10,000 for equipment. The salaries amount to over $27,000 annually, and the sum of $5,000 is given for current expenses. The bureau has been inaugurated under the most favorable auspices. Urged by scientific men and societies, on the one hand, and by engineers and manufacturers on the other, the bill passed both Houses of Congress almost without opposition. This was in large measure due to Secretary Gage and to the Hon. James H. Southard, Chairman of the Committee on Coinage, Weights and Measures, who gave the measure careful consideration and, impressed with its importance, used every effort to secure its passage. The President has already appointed a most excellent director in Professor Stratton, who has now leave of absence from the University of Chicago to take charge of the Bureau of Weights and Measures."

SMOKELESS FLASH LIGHT.

The magnesium flash light powders commonly employed for photography make, as everyone knows, a very disagreeable cloud of smoke. M. Charles

Henry has been experimenting with a view to doing away with this disagreeable feature. His results are communicated to *La Photographie* by M. L. P. Clerc, and are thus condensed in the *Revue Scientifique*:

"M. Charles Henry has endeavored to keep the magnesia that is formed as much as possible attached to a heavy substance that will not easily fly about and falls soon by its own weight—namely, the binoxid of barium. This substance, at a red heat, gives up half of its oxygen, and its salts communicate to flames a brilliancy of greenish fire, which partially corrects the undue proportion of violet and ultra-violet rays emitted by incandescent magnesia. Finally, the binoxid swells when heated and becomes capable of retaining the light powder of magnesia formed in contact with it. The sole condition to be observed, that the binoxid may be reduced with incandescence, is to remove it vigorously from all contact with oxygen. To this end, and also to insure the inflammability of the mixture, the powder is done up in collodion, whose products of combustion constitute a reducing atmosphere, adapted to the dissociation of the binoxid of barium at the lowest possible temperature; all the elements of such a powder thus play an active part at the highest point. These powders have, besides, a great advantage over those made of potassium chlorate; they are absolutely inexplodable by the stroke of a hammer, and are inodorous and without danger from the physiological point of view."

M. Henry, we are told, has prepared two types of powder that differ in their proportions of the binoxid; the first, which has only a little magnesium, gives only 45 to 50 per cent. of smoke, whereas ordinary powders give 75 to 90 per cent. The other is richer in magnesium, burns more slowly, and can be used advantageously only in a special lamp, when the proportion of smoke falls as low as 10 per cent., and the brilliancy, owing to the high temperature to which the magnesia is raised, is very great.

EXTENT OF THE TEXAS OIL FIELD.

Robert T. Hill, of the United States Geological Survey, who has just returned from a thorough geological investigation of the Texas oil district, has embodied the results in a report in which he says:

The importance of this oil field is far greater than at present can be described or estimated. It means not only a cheap fuel supply to the largest State in area in the Union, but, owing to its proximity to tidewater, it promises an export trade such as exists nowhere else in the world. Preparations are being made to sink hundreds of wells, and very soon the present output of 500,000 barrels a day may be quadrupled.

It is entirely within the limit of probability that oil will be found at many places throughout the coastal prairie, especially in its southern extension toward the Rio Grande and in the Northeastern State of Mexico at Tamalipas. The outcrop of the territory formations in Southwest Texas, in Wilson, Atascosa, McMullen, Duval and other counties is naturally rich in oil, and the practical oil men are risking their money in experimenting in that region. As the oil-bearing territory extends east of the Mississippi into Mississippi and Alabama, it is not beyond possibility that oil may be found in these States.

It is impossible now to state exactly the extent of the oil-yielding bed

which supplies the Beaumont well, and this can only be determined by drilling experiments.

The area of profitable exploitation of the Beaumont oil fields is confined between the San Jacinto and the Sabine rivers, east of the Houston & West Texas Railroad and south of Oil City, Nacogdoches County. This area may be extended or restricted by future exploitation.

It is very probable that other oil fields may be discovered in the coastal plain between Beaumont and Tampico fields. Here lies a vast territory, underlaid by the oil-bearing eocene formations which has not been exploited. W.

THE DETERIORATION OF PAPER.

A committee of the London Society of Arts which has had under investigation the causes of the deterioration of paper, announces the following conclusions:

The report makes special reference to the revolutionary changes in the paper industry that have taken place during the past century. They relate not only to the enormous growth of the industry, but specially to the introduction of new fabrics and materials which have taken their place as indispensable staples. Pulp made from wood is the most important of these new materials, and while it is admitted that it constitutes in many respects an efficient substitute, the conclusion is reached that many of these wood pulps are distinctly inferior in respect of the durability of the paper made from them than that made from the celluloses obtained from the old-fashioned materials, cotton, flax and hemp which were the exclusive staple materials for paper-making prior to the introduction of wood for the purpose.

The committee examined many specimens of deteriorated paper in books submitted to its members by librarians and others, some of which were in a state of complete disintegration, and made many independent examinations.

The report finds that papers exhibit a tendency to deteriorate in two days (1) by disintegration, and (2) by discoloration. These effects may occur independently or concurrently. Disintegration is notably exhibited in papers containing mechanical wood-pulp, although it was shown to occur in papers of all grades, from the best rag papers to the cheapest wood papers, though by no means to so great a degree in the former.

The disintegration was shown to be caused by the chemical changes taking place in the films themselves. In the case of rag papers the disintegration seemed to be due to acid bodies, while in the case of the wood pulp papers it was found to be due to oxidation, the effect being accomplished by a basic or alkaline reaction of the paper.

Papers of all grades were found to be susceptible to the second defect of discoloration, and without entering minutely into the chemistry of the changes, it suffices to state that this effect is traceable to the sizing operation to which all paper is subjected. It was the committee's purpose to give to its labors a practical value by the suggestion of standards of quality. With this object, the report presents the following specific suggestions for a normal standard of quality for book papers required for publications of permanent value, viz: Fibres: not less than 70 per cent. of fibres of the cotton flax or hemp class. Sizing: Not more than 2 per cent. rosin and finished with the normal acidity of pure alum. Loading: Not more than 10 per cent. mineral matter (ash). W.